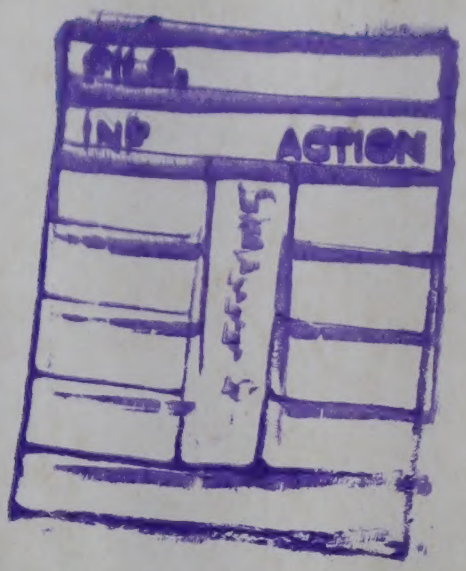
Tamil Nadu Nutrition Project

Volume One



A Study Sponsored by :
The Department of Food, Union Ministry of
Agriculture and Irrigation, New Delhi

November 1982

ADMINISTRATIVE STAFF COLLEGE OF INDIA
HYDERABAD-500 475

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Community Health Cell
Library and Documentation Unit
BANGALORE

Tamil Nadu Nutrition Project-I

1

Nutritional Aspects of Food Policy

2

Integrated Nutrition Planning Models

Project Leaders :
P K RAO, BALWANTH REDDY

November 1982

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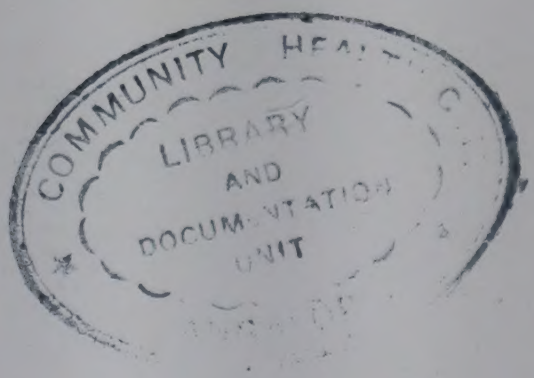

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Preface

The Government of India identified the Administrative Staff College of India, Hyderabad, for a study of Tamil Nadu nutrition. Accordingly, during 1976-77, the Department of Food (Food and Nutrition Board - FNB), Government of India, entrusted ASCI with two studies, in the first phase : (i) Nutrition Aspects of Food Policy; and (ii) Integrated Nutrition Planning Models, under the Tamil Nadu Nutrition Project (TNNP). In the next phase, ASCI was asked to take up the study of (iii) Demand for Nutrients, and (iv) Integrated Nutrition Planning. The Draft Reports of these studies were submitted to the Government : those relating to the first phase in 1979, and the others in 1981. Subsequently, we invited comments and suggestions for improving the studies, and we readily received useful and critical comments from a number of specialists and officials. A project review meeting was held in October 1981, and considered these comments. It was also decided to publish the studies after necessary revisions with a view to disseminating the findings to a wider audience; it is earnestly hoped that these reports will act as stimulants for further follow-up work in this important field and help implementation of nutrition policies, especially by the State governments; this, we would consider as our reward.

During the process of our investigations, we gained immensely from many senior officials. We are especially grateful to Shri Kamala Prasad (formerly Joint Secretary, Department of Food) for the enthusiastic and constant support, and appreciation of professional issues. We would like to gratefully acknowledge the co-operation we obtained from Shri S Rajagopalan (formerly Officer on Special Duty, TNNP), Shri T R Parameswaran (formerly Director, Department of Food), Dr P K Kymal (formerly Executive Director, FNB), Dr (Mrs) K K Sharma (Executive Director, FNB), Shri H D Bansal (Joint Secretary, Department of Food), and a number of senior officials of the Government of Tamil Nadu, especially Smt A Dayanand (Secretary, Social Welfare Department).

A number of professionals provided able assistance in various stages of work. Special mention must be made of Prof R Nagarajan and Shri A Thampy of the IIT, Madras Computer Centre, for arranging to process the data from the TNNP Data Bank. Among the colleagues at the College, we acknowledge the useful suggestions given by Dr Waheeduddin Khan at the stage of drafting some of the Reports. We are also grateful to : Shri K Hanumantha Rao (for the work relating to Report (i)), Ms. Mythili Ramakrishna (for the work relating to Chapter 2 of Report (ii)), Shri R Palani Velu (for a part of work relating to Chapter 3 of Report (ii)), Shri K Vijaya Kumar (for the empirical work and testing of Models in Report (ii)), Shri G K Mitra (for the computer programming and application in Report (iii)), Shri M Surendra Reddy and Ms. B K Malleswari (for their empirical work relating to Reports (iii) and (iv)). Shri V S A Durai, Editor, ASCI, ably edited the whole report and also co-ordinated the publication work.

The Project Leaders (P K Rao, Balwanth Reddy) shared the responsibility–the former undertook part of the work, supervised empirical work, and drafted the reports, while the latter provided the overall framework and supervision.

Shri T Ganeswara Rao, Shri Sunil Nagpal, Shri K Seshagiri Rao, Shri T R David, and a few others did the arduous task of typing and processing work at different stages; we are ever grateful for their co-operation.

November 1982 **P K Rao, Balwanth Reddy**

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1

Nutritional Aspects of Food Policy

1

Review of Food Policy

1.1 Introduction

The Constitution (Article 47), under the Directive Principles, states that "the State shall regard the raising of the level of nutrition, the standard of living, and the improvement of public health among its primary duties". Conventionally, food policy contains mainly components like pricing and distribution of food commodities, and direct and indirect intervention strategies of the Union and the State governments. However, in order to attain any desirable nutrition goals for the society, it is important to take an integrated view by examining alternatives in terms of extensity and intesnity of possible interventions. This calls for co-ordinated effort which influences agricultural production pattern, relative prices of agricultural commodities, trade system/regulations, market prices, buffer stocks, inter-State and inter-zonal movements, coverage of food items, quantities distributed through public distribution and pricing, sections of population and geographic regions covered for public distribution, feeding programmes and other complementary food intervention strategies.

The agricultural sector affects nutrition levels mainly in three ways : (a) production of crops for farm-level consumption (with their own processing and storage technologies); (b) production of crops leading to marketable surplus, which pass through the commercial food processing chains and markets to consumers; and (c) generation of income and employment which directly affect tha pattern and level of household food consumption. Since traditionally recognised

components of food policy, such as pricing (including support prices, levy prices, issue prices, etc, of foodgrains), procurement, rationing, buffer stocks and zonal movement restrictions (including imports/exports) affect the agricultural production pattern, it is necessary to take an overview of food and agricultural policies along with the nutritional implications of food policies. Thus, it is necessary to cover extended food policy for assessing the entire system to achieve the desired targets for nutritional development of the society.

Table 1 gives the changes in per capita net calories availability per day on an all-India basis computed year-wise for the period 1968-1980

Table 1 : Per Capital Net Calories Availability (From Foodgrains) Per Day (All India)

1968	1647.60
1969	1574.68
1970	1623.20
1971	1662.88
1972	1654.61
1973	1496.06
1974	1585.65
1975	1432.29
1976	1611.79
1977	1545.39
1978	1599.62
1979	1636.07
1980	1409.15

Source : (1) Bulletin in Food Statistics,1980
(2) Nutritive Value of Indian Foods. NIN, 1971.

The figures do not show any consistent secular trend in the improvement of availability. Also, considerable skewness in the distribution of foodgrains among different economic groups of the society shows the virtual non-existence of a continuing and effective nutrition intervention strategy for the improvement of the nutritional status. The Dandekar and Rath Line of Poverty based on nutritional norms has been used by many researchers to estimate the magnitude of poverty in the country. These studies, however, did not indicate any improvement in the nutritional status of the society as a whole ; the number of people below the poverty line are found to be on the increase for the last three decades.

We propose to examine in the subsequent sections of this report, important aspects of food policy. In this chapter, a historical review is made to examine the directions in which the food policy components have been moving during pre-independence and, post-independence eras and during the Five-Year plans along with their bearing on nutritional dimensions. In Chapter 2, the implications of various components of food policy on the nutritional dimensions will be examined. The last chapter summarises the findings of this study.

Food security has been traditionally interpreted as the provision of adequate and secure food supplies to a country or regional level. This definition suppresses the two important features:[1] (i) the problem of malnutrition especially inadequate calorie intake of low income groups due to the lack of necessary buying capacity for sufficient quantity and variety (quality) of food: (ii) constrained food availability low growth in agricultural output, variable yield and quality of producis/food basket composition (with reference to food preferences/tastes).

If the calorie responses to income increases are low, then 'normal' rates of income growth would have relatively

(1) Knudsen O, Scandizzo PL. Nutri ion and Food needs in Developing Countries. Staff Working Paper No. 328, 1979.

minor impact on eliminating malnutrition; direct intervention schemes (including food subsidies) would be needed to supplement market allocation of resources. Availability of quantity estimated as "food needs" is only a necessity but not always sufficient condition for eliminating malnutrition.

The authors estimated[2] that the poorest 10 per cent of the population in India have calorie response elasticity to income at 0.85, and those at poverty line have 0.59; that is, 10 per cent rise in income for people at poverty line would result in a 6-per cent rise in calorie intake and in case of the poorest 10 per cent group the rise would be about 8.5 per cent. The authors estimated that the annual income growth rate required to close the nutritional gap by 1995 for India would be about 3.3 per cent; alternately that about a quarter century would be required to close the nutrition gap at the given average per capita income growth rate and with no change in income distribution; however, if income distribution is going to be less equitable, it would require about 45 years for this purpose.

The estimated price elasticity for food for lowest 10 per cent income group is-0.76; at poverty line, it is-0.48. The price policies must be weighed such that the negative impact on nutrition status of price increases can be compensated either by income gains or direct food supplements. Income and food prices explain more than 90 per cent variance of calories intake both within each country and across countries, as examined in Morocco, India, Indonesia, Bangladesh, Pakistan and Sri Lanka.

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2. The estimated relations used were :

   $C = -2199 + 1135 \log Y$

   $\log C = 5.71 + 0.50 \log Y$

   Where C daily calorie intake per capita weighted by the Square root of the population proportion per class.

   Y : monthly expenditures weighted as above.

1.2 Pre-Independence Era

India's food policy, in specific terms, originated in early 1940's and "fair shares for all" became the guiding principle. In 1943, the Food Department introduced a basic plan, to distribute the excess in surplus States among the deficit States. As a consequence, a comprehensive scheme of controls consisting of procurement, imports, planned movements of supplies, and rationing came into force. With the fall of Burma (1942) along with the Bengal Famine (1943), the food situation became acute. The "Grow More Food" campaign considered several measures to increase the food supply which *inter-alia* include : a) double cropping, (b) switch over of production from non-food crops to food crops, (c) augmenting the supply of imported seeds, etc. Diverting land from non-food crops to food crops has to be considered carefully. During the Second World War, the government intended to grow rice and millets in the lands under cotton cultivation to meet the growing domestic demand. For this purpose, the government introduced special incentives, such as price support, procurement prices etc., to the producers of rice and millets and discontinuance of floor prices and transport facilities for short staple cotton. Though the government was successful in diverting the lands from cotton to foodgrains during war time, farmers switched over to earlier production pattern, after the end of the war and once the support was withdrawn. Moreover, diversion of cotton lands in favour of foodgrains resulted in reduction of feeder crops to cattle and in turn there was a fall in milk production.

The Foodgrains Policy Committee (1943) proposed(a) a food reserve of 5 lakh tonnes with the Centre to prevent breakdown of procurement, rationing and price control programmes (b) Introduction of rationing in all major urban areas both in surplus and deficit regions and progressive extension to smaller towns to secure equitable distribution. However,

only statutory rationing guarantees a minimum supply to meet the nutritional requirements (subject to ensuring purchasing power). The Foodgrains Policy Committee warned that the standard ration should not be allowed to fall below I lb/day/adult, which was consistent with the nutritional standards.

The Imperial Council of Agricultural Research (1944) had estimated the needed percentage increase in the production for 400 millions of Indians (as of 1945), based on the nutritional norms prescribed by the nutrition advisory grcup (1944, which were revised later) and the estimates are given below :

Cereals 10 percent, pulses 20 per cent, fats and oils 250 per cent, fruits 50 per cent, vegetables 100 per cent, milk 300 per cent, Fish and eggs 300 per cent.

The above estimates indicate : (i) the serious deficiency in case of vitamin A, iron and protein among others, and (ii) the need for intensifying production of supplementary foods. The Nutrition Advisory Committee (1944) observed that it was more feasible to increase the production of cereals than other foods up to the required standard, and that emphasis must be laid on more cereals as part of short-term production policy[3]. The Famine Inquiry Commission (1945) agreed with the Nutrition Advisory Committee's remark. It suggested that since cereal was the staple food of the population, self-sufficiency in cereals, at a satisfactory level of intake should be a candinal aim of the food and agricultural policy. However self-sufficiency in cereals does not guarantee food for all nor nutrition at desired levels. Moreover, the production possibility of cereals cannot be considered in isolation of other foods. For example, to increase milk

3. The average intake of cereals in India was higher than the cereal consumption in developed countries. What may be required is that calories should be provided through non-cereal food items. Another fact is that increase of cereal production may result in a fall in the availability of pulses and legumes— sources of proteins.

production more land should be diverted to fodder crops and pastures. The production possibilities are also constrained by geo-physical factors. The Famine Inquiry Commission, therefore, suggested the popularisation of soyabean and soyabean flour, which are rich in protein and other nutrients used as a fodder and as rotation crop. The acceptability of soyabean as food item by the masses is doubtful on the ground of palatability. It is reported that defatted soya flour has been used in largescale feeding programmes and is also being imported by foreign agencies sponsoring such feeding programmes and that there was no significant problem of palatability. However, an important issue that needs to be examined further is palatability at what cost, considering the raw material as well as processing costs, the cost per unit nutrient would be a useful indicator for guiding policy governing soyabean processing technology/industry.

The Fifth All-India Food Conference (February 1945) pointed out that all-India planning would be necessary to correlate the demand with cropping pattern and production. If the food policy aims at producing or supplying more calories at low cost simultaneously economising the use of land, non-cereal products, such as potatoes, tapioca, which provide higher calorie yield per unit area than cereals and pulses, could be grown. This alternative however poses some problems. The acceptance of these food items as the main ingredient of the diet, and consuming these products as staple item could bring about reduction in protein intake.[4] So, to have a balanced diet, animal foods are to be supplemented. Their choice will adversely affect the nutritional status of the vulnerable groups since the animal foods would not be within their reach. Therefore, one has to examine the possible intake of items like potato, in conjunction with the intake possibilities of complementing items like animal products.

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4. Besides acceptability, one should consider the economic costs of fortification of these items with other nutrients.

In January 1946, the Union Government took upon itself the responsibility of providing "enough food" for all, sufficient in "quantity" and of requisite "quality". It considered a package of programmes, prominent among them being (a) grow more food, (b) marketing system for agricultural products at prices remunerative to producers and fair to consumers, (c) fair wages for agricultural labourers and higher standard of living for rural communities, and (d) fair distribution of food. The development of an efficient marketing system for agricultural products implies restricting the role of intermediaries and their trade margins. An increase in income is a necessary condition, however, not sufficient enough to the improvement of diet. For instance, when incomes of the poor rise, the shift may be from millets to rice; from hand-pounded to polished rice, incurring nutritional loss.

Thus, the main emphasis of the pre-independence era was to provide necessary quantities of foodgrains so that law and order violations do not occur on account of starvation-semi-starvation. Naturally, the objective of fulfillment of nutrition requirements of population was far too elusive for consideration of the erstwhile rulers.

1.3 Post-Independence Era

As there was no marked improvement in the production of protective foods since 1939, the Government of India appointed Subsidiary Food Production Committee (1949) to study production, storage, and utilisation of subsidiary foods. Some of the prominent recommendations were : (a) expansion of area under cultivation of banana, tapioca, and sweet potato, (b) production of groundnut flour at a cheaper cost, to meet the protein deficiency and supplying it through ration at a low price and replacing a part of cereals, (c) guaranteeing the producers of protective foods the sale of their produce, and (d) for effective utilisation, these to be procured by, the government and supplied to consumers under

public distribution system. Though groundnuts contain quality proteins, replacing a part of cereals–, a source of energy— by groudnuts through ration is a questionable proposition in view of the prevalent calorie deficiency, besides protein deficiency. We should also note that, unless a critical level of calorie intake is assured, proteins will not be used metabolically to serve the normal purpose of proteins, but get converted into calories. In respect of the procurement of protective foods, special measures and care are needed in transport and storage.

The principal objectives of India's food policy in the post-independence era, were : (a) self-sufficiency, (b) equitable distribution, and (c) price stabilisation. These goals were accepted by the Foodgrains Enquiry Committee (1957), the Agricultural Price Commission (1965), and the Foodgrains Policy Committee (1966). But the choice of policy instruments and type of government's interventions recommended by these committees were different. The Five-Year Plans incorporated several special schemes and programmes to achieve these goals. The First Plan regarded controls like procurement and rationing together with minimum level of imports as essential for a stable food situation. Monopoly procurement or levy was opted for procuring marketable surpluses and urban areas above a certain size, depending upon the regional/local conditions, were brought under statutory rationing. To protect the interests of the producers and consumers and to increase the productivity and output, a system of controls, such as regulation of prices and trade by government, movement restrictions, etc, were adopted. The Second Plan fixed some nutritional targets. It aimed at increasing the per capita consumption of cereals to 15.5 ounces and pulses to 2.8 ounces (for adults) by the end of the plan period. In other words, it was expected that the daily calorie intake per adult would increase from 2,200 to 2,450 calories by 1960-61. It was also planned to increase the per capita consumption of milk from 5 ounces gradually,

and to supply milk to urban areas at prices acceptable to both the producers and consumers. An integrated approach to agricultural planning comprising planning of land use, appropriate price policy, etc, to augment the supply of nutrients was suggested. Maintenance of buffer stocks of foodgrains was emphasised to mitigate sharp price fluctuations and to meet exigencies. The Third Plan contained a number of programmes to increase production of subsidiary foods, to diversify the pattern of food consumption, and to promote balanced nutrition. Integration of agriculture with animal husbandry was emphasised more for economic utilisation of factors of production: generating more employment and for increasing rural incomes which, in turn, will improve the nutritional status. The government had considered nutrition as an integral part of food policy, for the first time in the Fourth Plan. In this, the plan document states : "where so many are undernourished, more food is the first step towards better nutrition. In this sense, therefore, the nation-wide endeavour to develop agriculture along with animal husbandry and fisheries must be regarded as the base of all effort in nutrition. In the very process of production including the planning for different crops, it is both necessary and possible to provide for the main needs of good nutrition". It recognised that in the improvement of qualiiy of staple diets, cereals can be efficacious means of raising the nutritional level. The long-term object of the Fifth Plan was to improve the nutritional status of the community through augmentation of production and economic upliftment. For increasing the protein availability target for pulses production was fixed at 14 million tonnes. It was attempted to frame the pricing policy to : (a) provide incentive for sustained and higher production; (b) evolve the desired cropping pattern; and (c) normalise procurement and distribution operations to protect the interests of consumers, particularly of vulnerable groups.

In a study of nutrients, one has to consider measures undertaken in respect or fisheris, poultry, etc, since non-food

grain food items will also provide nutrients (in some cases high quality nutrients.) Some important programmes initiated during the-five year plans regarding fisheries, poultry, and dairying are mentioned in the following paragraphs.

Improvement of fisheries. poultry and dairy farming considerably strengthen the future nutritional position. Fish is one of the sources of animal proteins, fat, fat soluble vitamins, and minerals. In underdeveloped and developing countries where transport and technological facilities are yet to develop to their fullest potential, popularising fish meal is one of the alternatives for economic utilisation of the existing nutrients. Therefore, the Fourth Plan proposed to expand the processing, marketing, and storage facilities for flsheries. The Fifth Plan envisaged a strategy for fisheries development by augmenting additional nursery area for fish seed production, deep sea fishing through mechanised boats, and fish processing through improved methods of handling, salting, and dehydration. The Sixth Plan (1980-85) considered that the fisheries offer a large scope to fulfil the basic objective of production-cum-full employment; increased fish production would considerably help in filling the gap between the availability and requirements of high quality protein subsidiary for internal consumption at reasonable prices. The Sixth Plan further proposed to give top priority to off-shore and deep-sea fishing by encouraging research and commercial surveys, experimental fishing for market assessment, etc. considerable increase in marine fleet through incentives and judicious selection in size and type of fishing vessels would be undertaken. The fact that the utilisation of marine foods is steadily increasing is evident from Table 2. We may note from the table that the percentage of marine foods consumed has gone up between 1968 and 1973 in case of fresh, frozen, and canned foods, whereas in the case of industrial fish, it declined, while smoked fish and others have registered no change.

Table 2 : Utilisation of Marine Products at Global Level (in percentage)

Human consumption	1968	1973
Fresh	28.3	30.6
Frozen	12.7	18.3
Smoked	12.7	12.3
Canned	8.7	10.6
Industrial fish	36.0	26.7
Others	1.0	1.5
	100.00	100.00

Source : Food resources of the sea; some economic problems relating to their utilisation. *Food and nutrition* 1977, 3 (1), p. 15.

Since egg and milk are the most commonly consumed nutritious foods of the day, poultry production has in the last decade, made rapid strides. The annual egg production increased by 300 per cent, from 2,500 million eggs, in 1961 to about 10,000 million eggs in 1977. The production of poultry meat (through broiler production) has also gone up considerably, to about 17 million in 1977-78, from 4 million in 1971. But despite its rapid growth, the poultry farming is largely confined to urban and semi-urban areas only as most of the poultry development schemes are normally around these areas. This bias against implementation of these programmes in rural areas brings about inadequate availability of these items in rural areas. To overcome this deficit, the Sixth Plan proposes to implement these programmes in districts, to create a shift in its production schemes to the rural sector and also to create additional employment and supplementary income

to small and marginal farmers and agricultural labourers. It is also proposed to establisn Poultry Corporation of India during this plan period.Under this establishment it is expected to give impetus to broiler production, processing, and marketing. The targets of fisheries and live-stock production during Sixth Plan are presented in Table 3.

Table 3 : Targets of Fisheries and Live-stock Production

Fish production	Unit	Likely level of production in 1979-80	Target 1984-85
Inland	Lakh tonnes	8.55	13.00
Marine	,,	14.81	22.00
Total	,,	23.36	35.00
Milk	Million tonnes	30.00	38.00
Eggs	Million Nos	12,320	16,300

Source : Sixth Plan (1980–85), Govt. of India, pp. 130, 134.

A study by Bhote and Jayaraman[5] shows that in Tamil Nadu, the average per capita consumption of milk has increased over a decade, from 77 gms/day in 1951 to 83 gms/day in 1961. Improving the network of dairy farms spatially will enable the proper distribution of milk and act as an incentive for increasing milk production. It may be recalled that due to Anand Milk Scheme in Charton Village in Gujarat, the value of milk produced has increased by Rs. 0.1. lakh over the cost of agricultural production in 1958-59.[6] This scheme ensured guaranteed fair price and

5. Bhote R A, Jayaraman S. Trends in milk production during 1956-61. Agricultural Situation in India, Volume 22, p. 663.
6. Sivaraman B. Nutrition in Rural India. In the Fifth Plan. Proc. Nutr. Soc. India., No. 17., 1974. pp. 8-12.

regular payment and collection of milk produced in the village. Apart from this, animal husbandry schemes have been introduced to ensure the optimum yield and better health to the animals. Following the Anand Pattern, and adopting the cross breeding programme of animals, it is proposed to develop milk production as a subsidiary industry in the rural areas. The programme should be aimed at small and marginal farmers by giving them the necessary facilities, and encouragement in view of the lack of purchasing power in lower income gorups in rural areas as this generates employment also. Livestock development was given due importance based on nutritional upliftment in the Fourth Plan period.

An integrated approach/planing for the development of these various schemes, such as dairy, poultry, and fisheries, is a necessary pre-requisite for creating adequate market for all the commodities. Dividing the State into two or three regions and setting up of dairy farms at regional levels and developing the poultry farming from village level so as to cater to the urban and rural needs and ensuring adequate income to the rural poor are some of the programmes needed. There is also an urgent need to improve poultry farming and to ensure egg production at cheaper prices,as the lower income groups are otherwise unable to ensure them.

1.4 Nutrition Programmes during Five-Year Plans

Investigations before and during the First and Second Five-Year Plans showed that malnutrition was acute among the school-going children. In order to ameliorate this the First Plan advocated feeding programmes and setting up of public health departments to look after the needs of infants, children, and mothers. It was also decided to develop and manufacture synthetic vitamins and shark liver oil industry. In the Second Plan period, distribution of milk powder, cod liver oil and vitamins to vulnerable groups were proposed as special measures. Emphasis was also laid on provision of mid-day meals to school-going children.

In the Third plan, it was proposed to inform and guide the public opinion about the conservation of nutritive elements in food; for this, promotion of nutrition education was made an essential programme. Training programmes in nutrition for doctors, teachers, etc. were suggested, and the establishment of special sections for nutrition in public health department in the States was urged. A well designed nutrition progromme at district and block levels was also suggested. Towards this,734 blocks were brought under the applied nutrition programmes by the end of 1968-69. Nearly 11 million children were coverd by the mid-day meal programe and 2 lakh and 5 lakh children were fed through balwadies and nutrition feeding programmes, respectively.

The Fourth plan proposed an integrated nutrition programme and fixed priorities with reference to needs, classes, and areas to improve the efficient coverage of the involved organisations. New schemes were recommended for curing anaemia, blindness, and protein deficiency. Protein malnutrition was identified as a dominant problem and attention was paid to areas of acute malnutrition. Schemes for pre-school children (Balwadies) and nursing mothers were launched. The creation of a new organisational network involving women for benefiting the children was proposed. The nutrition of project included were: (a) production and promotion of cheap and nutritious food; (b) research on fortification of food products with specific nutrients; and (c) research for the production of unconventional protein foods. For supplementing the diet of the pre-school and school-going children, the unconventional protein foods, such as Balahar, soyabean, groundnut flour, etc, were suggested. It was proposed that the pre-school and school children should be served together to increase the impact of nutrition programmes. A detailed scheme of the outlay and targets can be had from Tables 4 and 5.

Table 4: Schemewise Outlay for Nutrition in the Fourth Plan

	Scheme	Outlay proposed (Rs. lakhs)	Remarks
1	Department of Health and Family Planning	513	
2	Feasibility tests of vitamin and mineral fortification of staple foods	3	Central scheme (new)
3	Pilot project for nutrition education through State Nutrition Bureau	3	Central scheme (new)
4	Prophylaxis against nutritional anaemia in mothers and Children	405	Central scheme (new) (this represents rupee outlay on domestically available components mainly ferrous sulphate)
5	Control of blindness in children caused by vitamin A deficiency	102	Central scheme (new)
6	Applied nutrition programme	1,000	Centrally sponsored (continuing scheme)
7	Composite programme for women and pre-school children	600	New scheme
8	Production of groundnut flour and soyabean products	92	Central scheme (continuing)
9	Production of balahar and low cost protein foods	670.57	Central scheme (continuing)

10	Production of weaning food	20	Central scheme (continuing)
11	Pilot plant for protein isolate and protein isolate tinned milk	40	–do–
12	Cotton seed flour	15	Central scheme (new)
13	Fortification of salt	32	–do–
14	Fortification of wheat products	50	–do–
15	Fortification of bread	1	–do–
16	Maize, pulse and millet processing	8	Central scheme (continuing)
17	Fruit products and cold storage scheme	57	–do–
18	School feeding	500	State sector
19	Nutrition feeding of pre-school children through Balwadis	600	Central sector
20	Total outlay	4.518	

Table 5 : Physical Targets of Nutrition Scheme

Scheme	Unit	Fourth Plan Target
Department of Health and Family Planning		
Prophylaxis against nutritional anaemia in mothers and children	Beneficiary coverage in million	15
Control of blindness in children caused by vita-	Children covered in million	8

min A deficiency Department of Community Development		
Applied nutrition programmes	New blocks	450
Composite programme for women and pre-school children	Blocks benefitted	1,200
Production of balahar Department of Education	Lakh tonnes	2.5
School feeding programmes	Children covered (6-11) in million	14

Source : Fourth Five-Year Plan (1969-74). Planning Commission, pp. 242-44.

For implementing the nutrition programmes, the establishment of a high powered organisation is necessary. Organisation and active participation at the State level is considered as of vital importance. A separate report entitled Coordination, Monitoring and Evaluation of Nutrition Programmes deals with the existing practices and scope for improvement.

As against the target of covering 14 million children through mid-day meals feeding programme (for 200 days in a year), only 12 million children (including one million pre-school children) were fed. Special feeding programmes for children of 0–3 years age in tribal and slum areas of metropolitan cities launched in 1970-71 by the Social Welfare Department, were extended to children up to 6 years, pregnant women and lactating mothers. Under this programme, daily 300 calories and 10 to 15 gms of proteins for children and 500 calories and 20 gms of proteins for women (pregnant and lactating) were supplemented. This service was rendered for 300 days in a year through 28,000 feeding centres covering 38 lakh beneficiaries. Doses of vitamin A were given to 11 lakh children (1–5 years age) by the end of 1971–72. To

contain nutrition anaemia, iron and folic acid were supplied to 10 lakh children and mothers. Nearly 450 new blocks were brought under the applied nutrition programmes.

In the Fifth Plan, under the Minimum Needs Programme, priority was accorded to the improvement of nutritional status of women (lactating and pregnant) and pre-school children. Deficiencies of calorie-protein, iron, and vitamin A were identified as the major nutritional problems. An integrated approach to supplement feeding programmes was advocated and the feeding programmes were proposed to be integrated with health and welfare programmes (minimum health care, immunisation and environmental sanitation). The outlays, targets and coverage of nutrition programmes for this are given in Tables 6 and 7. The utilisation of locally available foods for feeding programmes have been encouraged to minimise transport costs. For the maximum utilisation of local foods, preservation and packaging techniques were under study. A Nutrition Development Corporation was proposed to be set up under the Department of Food to produce nutritious foods for supplementary feeding programmes and weaning foods on a commercial basis. During this plan, 700 additional blocks were to be covered and integrated child care services were initiated in some of the applied nutrition blocks. Research in nutrition education, surveys, take home feeding experiments, etc, were advocated. Evaluation of major nutrition programmes was proposed and it included formulation of guidelines for evaluation of the schemes by experts. The setting up of a Central Co-ordination Committee in the Planning Commission was recommended to co-ordinate the nutrition activities of the Centre and State governments.

Table 6 : Outlay for Nutrition Programmes in Fifth Five-Year Plan
(1974-79)

(Rs. crores)

Name of programme	Sector	Estimated outlay
Programme of the Department of Food (pilot projects, food production and processing, research etc.)	Central (A provision of Rs. 2 crores is earmarked for evaluation of all major nutrition programmes from this allocation)	50.00
Programmes of the Department of Community Development	Centrally sponsored	20.00*
Programmes of the Department of Health & Family Planning (supplementation of vitamin A, iron & folic acid)	Centrally sponsored	5.00
Programmes of the Department of Education-midday meal programmes	State sector	112.00**
Supplementary feeding programme for children in the age group 0–5, pregnant women and lactating mothers in tribal areas, urban slums and chronically drought-prone areas	State Sector	218.00
Total		405.00

*Excluding provision for integrated child care services which is being shown in the Social Welfare Sector

**Excluding CARE assistance which is likely to continue at the 1973–74 level in the Fifth Plan

Source : Draft Fifth Five-Year Plan (1974-79). Vol II. P. 256

Table 7 : Targets of the Nutrition Programmes

Nutrition Programme	Unit	Fifth Plan Target
Applied nutrition programmes	Additional blocks	700
Mid-day meal programme	Million children	16.5
Special nutrition programme	Children + women (Pregnant & lactating in million)	10
Production of balahar	Lakh tonnes/annum	2.5

Source : Draft Fifth Five-Year Plan (1974-79); vol. 2, pp. 244-46

The Sixth Plan (1978-83) identified the integrated rural development and the creation of adequate employment opportunities as better measure of solving the nutrition problem than continuing the supplementary feeding programmes on a permanent basis. However, the nutrition programmes will be confined to backward rural areas and to the severely malnourished. The different components of nutrition programmes—production, processing, supply or distribution, consumption and efficient utilisation of foods—will be properly co-ordinated by involving the concerned ministries. Efforts will be made to intensify the production of low-cost nutrition foods and fortification of foodstuffs. For instance, it is proposed to increase the production, in a phased manner, of balahar and other low cost foods prepared from locally available raw materials. To combat the existing nutrient deficiencies the fortification of foods with specific nutrients will be intensified.

It was proposed to provide, under supplementary nutrition programmes, about 300 calories and 15 gms of protein per child per day for a period of 200 days in a year as part of

the mid-day meals programme. The daiiy nutrient supply will be about 200 to 300 calories and 8 to 12 grams of protein per pre-school child for about 300 days in a year. The outlays of the Sixth Five-Year Plan (for this) are given in Table 8.

Table 8 : Sixth Plan Outlays on Nutrition

A.	Nutrition Programmes of the Department of Food : (Central sector)	
	a) Diet surveys and nutrition planning (Rs. crores)	1.65
	b) Nutrition education and extension	1.75
	c) Production of nutritious beverages	0.60
	d) Production of nutritious foods	
	i) Balahar	3.50
	ii) Extraded foods	0.20
	e) Fortification of salt	4.00
	f) Fortification of milk	1.00
	g) Fortification of other foods	0.10
	h) R & D activities and evaluation	0.50
	i) Scheme for imparting integrated education in nutrition, health, hygiene and sanitation	1.00
B.	Applied nutrition programme of the Dept. of Rural Reconstruction (Central sector)	1.00
C.	Total in the Central sector	14.95
D.	Total in the State sector (State/UTs)	223.19*

* inclusive of the Minimum Needs Programme component of Rs. 218.74 crores

Source: Sixth Five-Year Plan (1980-85)

It has been argued that these feeding programmes do not serve the purpose, if they are not on a continuous basis and if feeding is not made for the prescribed number of days or if there is uneconomic utilisation of scarce resources. Another observation about the feeding programmes was the lack of evalation of these schemes on a systematic and scientific basis and that there is need to prescribe norms for such evaluation.

By now it is an accepted fact that industrialisation and urbanisation increase the demand for processed foods. Care should be taken that these processed industries use only surplus agricultural produce. The diversion of primary foods for conversion into processed and sophisticated foods to meet the consumer demands of urban area should be restricted to surplus foods only, unless justified otherwise. For this, a detailed social cost-benefit analysis is needed in order to suggest specifically which of the foods can be processed for preserving and processing, with reference to the objectives—consumer welfare of the desired/target population(with price stability and new/additional or consumption benefit), and other considerations of employment potential, household income of consumers and producers.

The supplementary programmes can be made more effective through education and choice of cheap and locally available foods. The supplementary programmes should be implemented as a component of wider range of far-reaching and long lasting nutrition intervention programmes. The success of the programmes will be marginal if the concerned organisations lack purposive efficiency.

Minimum Needs Programme — Sixth Five Year Plan (1980-85) : In this, the nutrition component has two parts : (a) special nutrition, and (b) Mid-day meals.

(a) Special natrition introduced on the non-plan side in 1970-71 and was brought into the Fifth Plan as part of MNP; it provides 300 calories, 8–12 gms protein for the 0–6

years for 300 days and 500 calories and 25 gms protein for pregnant and nursing women for 300 days. The targets as of April 1980 are 7 and 70 m., respectively.

The programme is likely to achieve a cumulative coverage of 8.18 m (5.73m outside the plan or 2.45 under the plans by March 1980). The programme would be expanded to cover additional 400 ICDS projects. Thus, additional 5 million children and 50,000 women would be covered in the plan period.

(b) Mid-day meals scheme was introduced in is 1962–63 for the group 6-11 years; provides for 200 days a year 300 calories 8–12 gms protein. About 15.1 million children are being covered outside the plan and 2.3 million under the plan. Recent studies have shown that the scheme has not made much impact in enrolment or in reducing the drop-out ratio. It would, therefore, be necessary to reorganise it and link it with health services, safe drinking water, environmental and personal hygiene, incentive schemes and kitchen and horticultural garden in the schools, from where vegetables and fruits would be available for the feeding programmes, before any further expansion is undertaken. The total cost of nutrition programme for 1980-85 is placed at Rs. 219 crores non-MNP component in the total outlay for States/UTs is marginal, the total being Rs. 223.19 crores (including ANP, etc).

The problems of malnutrition, morbidity and mortality have been recognised since the Second Five-Year Plan and a number of schemes have been introduced for combating them. These schemes formed part of components of health sector in the first three Five-Year Plans; In the Fourth Five-Year Plan an integrated nutrition programme with an outlay of Rs. 45.18 crores was introduced (which was later reduced to Rs. 42.5 crores). Over the subsequent Five-Year Plans the supplementary nutrition feeding schemes multiplied in variety, coverage

groups and areas and also in terms of components of different schemes. A brief review of these is contained in the Sixth Five-Year Plan Document. A summary of this and other findings is reported in a separate supplementary report in this series under the title Co-ordination, Monitoring, and Evaluation of Nutrition Programmes.

An important outcome of the sectoral and restrictive approach to nutrition is the proliferation of pilot projects (which subsequently gain inertia and often stand to continue, particularly in the absence of adequate ex-post evaluation of the schemes/programmes). "Every pilot project whether it is for school feeding, child feeding or the feeding of the vulnerable groups becomes a straight-jacket of administrative arrangement ..., as we move from one set of a pilot project to another with a distinctive brand name catering to specific set of beneficiaries, the solutions get more and more fragmented"[7].

7. Prasad K. : *Policy for Nutrition Intervention*. Workshop on Nutrition Planning, ASCI, Hyderabad, 1980.

2

Food Policy Components and Their Rate

Introduction

Higher stage of economic development could, largely, bring about the elimination of under-nutrition. It does not, however, follow that to ensure better nutritional status, the only way is to attain high level of economic development—which is generally a long-term and arduous process, especially for the underdeveloped countries. Therefore, given the targets of upliftment of the poor, who generally form the vulnerable sections of society from the nutrition viewpoint as well, it is relevant to examine the policy interventions necessary for ensuring commensurate supply and adequate nutritional intake. The benefits of effective nutrition intervention programme by far outweigh the costs involved.

A brief review of the food policy prior to and during five-year plans will help a better understanding of the implied nutritional approaches. Apparently, in most of the policies, at least till the Fourth Plan, there was no explicit recognition of the need for rectifying deficiencies in nutritional status of the society. This may partly be the main concern being how to feed the hungry masses. Also, nutritional dimensions were treated as part of public health policy and the attention paid was much less than what was needed. Now that the situation on the food front is comfortable, we should take persistent interest in directing the food policy and other measures to achieve better nutritional status to the society.

Social policy cannot wait till such time there is general economic development, generating the needed purchasing power and implicit improvement in nutritional status eliminating the nutritional deficiencies of the weaker sections. In the shortor medium-term, interventions making use of the various economic and other policies affecting production and consumption systems and biological utilisation needs, must be evolved. There are several parameters, such as prices policy, incomes policy, procurement/distribution, environment, and hygiene, which influence these systems. In designing a purposive food policy, one has to bear in mind, *inter alia*, the impact of different components of food policy on the vulnerable segments of population: age-group-wise and economic status-wise. The serious long-term effects of malnutrition on the sensitive age-groups and on women during pregnancy warrant prior attention to be paid to these segments of intervention like special feeding programmes may be designed using the cost effectiveness analysis.

Planning of production for food items solely from nutrition angle may lead to some discrepancy between the potential for different items under the given agro-climatic and technological conditions and the preferred pattern to optimise the supply of nutrients to the society. Planning for intervention should aim at minimising these discrepancies wherever they occur. Some components of food policy like pricing and procurement should be utilised for this purpose. Similarly, the scope for affecting the consumer demand system or achieving the ideal nutritional status for all people is also constrained by factors like food preferences by taste, traditional habits, lack of nutritional education, etc. However, among the poorer sections of the population in which quantitative intake of food is itself inadequate, the priority in policy would be to ensure the availability of food commodities at reasonable market prices or via the public distribution system, which is essentially the function of a food policy. We shall deal with the nutritional implications of the main

components of the food policy in the subsequent paragraphs and see how these components affect the production as well as consumption systems, confining our attention to pricing, procurement, public distribution, buffer stocks, imports and trade regulation, and components of food policy.

2.2 Pricing

Obviously pricing has a crucial role in determining production and consumption. When we refer to pricing it is not merely to the direct regulation or controlled pricing but also to a host of related policies which influence both directly and indirectly the multiple prices operating for each of the food commodities, be it support price, levy price/procurement price, open market price or issues price in the public distribution system. Since real subsidy may be called for in the context of the welfare of the poorer sections by fixation of appropriate price and quantity (distribution at controlled price) of the food items their aspects needs must be investigated as to how best the real income and hence the nutritional status could be augmented.

The identification of the components of pricing, briefly mentioned above, would help in analysing the nutritional implications of the different alternatives to these ingredients. In formulating guidelines for pricing, the impact of different types of intervention on both production and consumption fronts and also in conjunction with the price, production and consumption behaviour of related commodities have to be examined. The desirable extensity and intensity of public distribution over the various sections of people has also to be looked into. In the past, the public distribution system covering some sections of the society was mainly confined to rice, wheat, and other coarse cereals which normally yield calories and a little of other nutrients. It is necessary to examine the relevance and feasibility of extending the coverage of commodities for improving the nutritional status. The impor-

tant issues that one should study are : a) the commodities that are distributed to different groups; b) the quanta of different items issued to different segments of the population; c) the prices at which these commodities are supplied to various sections of the society; and d) the prices at which commodities are procured.

The role of pricing in production of nutritious goods is proposed to be examined for suggesting some intervention programmes to achieve the desired results. Wherever, possible, some hypothetical situations for the purpose of illustration will be discussed. The relative impact of various intervention schemes, such as procurement price and quantity are bound to be dependent upon the class of farmers and their behaviour in taking production decisions. Therefore the characteristics of each of these classes in terms of the possible objectives and constraints like meeting the subsistence requirements or maximisation of profits have to be recongised. This helps in evolving a suitable policy for agricultural inputs. On the production side, the government has been making use of support price and procurement price, as insiruments of price policy. We should examine whether such prices have influenced/encouraged the production of nutritious foods or production of those crops which provide more nutrients to the society.

The Agricultural Prices Commission has been recommending procurement/minimum support prices for major foodgrains for kharif and rabi seasons, with a view to directing the cropping pattern in the desirable directions and stabilising the farmers' incomes in case of gluts. However, while aiming at the desired cropping pattern, no serious attempt seems to have been made to incorporate the nutritional dimensions of different crops and varieties. For partially supplementing the nutrition' development objectives of the society it is necessary to encourage such varieties of grains that will provide higher effective nutrient supply for a given set of agricultural inputs.

Though support prices have been announced for most of the cereals, these prices have not practically played any significant role. Since these prices are in the nature of insurance to protect the interests of producers in critical periods they have not been able to influence the producer's decisions. This leads us to the conclusion that the nutritional impact of support price is almost negligible. However, a discerning study of the earlier agricultural policies shows that the nutritional dimension of this policy instrument can be made positive, if support prices were announced early and cover the cost of production. In future, these prices should be offered to the producers who adopt high-yielding varieties and seeds of high nutritive value.

The purpose behind the procurement price is that the government intends to procure a part of the domestic supply to feed the poor in the urban and/or rural areas. Usually, the procurement price will be lower than the market price and in practice, it should act as a minimum guarantee price to the producer and as an incentive for production.

The nutritional implications of these prices can be positive or negative. For instance, if price incentives were offered to one of the two varieties of a commodity, say, rice whose calorie content is almost the same, then the nutritional impact will be different. The nutritional implications have to be judged, by taking into account the yield rates and the protein content. If food planning aims at economic use of scarce land as well as maximisation of total supply of nutrients, one has to investigate the technical feasibilities and the costs of production of nutrient-equivalent as well as the total output of competing alternative crops. In the case of tuber crops like potato and tapioca, the yield per hectare of tapioca and potato are about 265 lakhs and 73 lakhs, respectively, and these are about 40 lakhs and 19 lakhs in the case of rice and jowar,

respectively.[6] Subject to satisfying hydrogeological requirements it looks like these crops need to be encouraged.

Recently, the Union Government has been encouraging the large-scale production of potatoes, in view of their nutritinous value as well as export potential. Since potatoes can be grown as mixed crop, from the nutrition point of view, the government's decision is worth considering. However, the storage aspects and the cost implications of this commodity have to be examined. Appropriate pricing policy for potatoes is, therefore, necessary to make it a staple food; under given consumer food habits, its acceptability in greater doses in diet may pose a problem (apart from preservation).However, nutrition education may help increasing its consumption. Lipton [7]. observed a decline in the availability of coarse cereals, the staple diet for most of the rural poor, and a rise in the prices of these commodities. From the nutrition point of view, discouraging the production of coarse cereals (except in dry land areas where the efforts should be intensified through research activities, to maximise the yield) may be warranted only in special cases.

The decision on issue prices is taken at two stages : (i) when the Central Government fixes the issue price while foodgrains are issued to the States from the central pool; (ii) when the States issue foodgrains to the Fair Price Shops (FPS) and the ration shops, when the price is fixed by adding different kinds of surcharge, taxes, price equalisation margin and the like. These margins differ in different States and as a result, the final issue prices differ among States. For example, in Punjab the difference between the Central Government issue prices and the retail issue prices is around Rs. 6 and

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6. Estimates of Area and production of principal crops in India 1974-75. The figures correspond to the year 1973-74.

7. Michael Lipton. Urban bias and food policy in poor countries. *Food Policy*. Nov. 1975, pp. 1-52

Rs. 10 per quintal for wheat and rice, respectively, while in Andhra Pradesh for rice is to the extent of Rs. 20 per quintal. Similarly, in Tamil Nadu this margin is about Rs. 35 for rice, and Rs. 17 for atta (wheat).

The basic question that arises in fixing the issue prices is : whether they are reasonable to consumers, particularly to the vulnerable section of the community. Ths answer would obviously depend upon the following two factors: (s) quantity issued per person, and (ii) the difference between the open market and issue prices. In the case of statutory rationing, however, the consumer is supposed to get the full requirement (nutritional) at the issue prices which are normally lower than the open market prices. Therefore, this form of rationing is in conformity with the objective of equitable distribution at reasonable prices. Whether the same objective is also achieved in informal rationing areas has to be judged, both in terms of quantity and price.

Since the issue prices of commodities play a vital role in improving the nutritional status of the specific groups, such commodities should be within the reach of the vulnerables. For example, the price elasticity of foodgrains demand in India is about 0.35 in rural areas and 0.5 in urban sectors[8] thus whenever foodgrains prices go up (falls) by 10 per cent, the demand declines (increases) by 3.5 per cent in rural and by 5 per cent in urban areas, respectively, worsening an already unsatisfactory nutrition situation. A fall in prices will increase the real incomes and in cases where the demand for foodgrains is satisfied, it will result in the increased consumption of other food items, So, if staple foodgrains were issued by the public authorities to the low-income groups, at low prices, then either the grain (calorie and some marginal amounts of other nutrients) intake or the intake of other foods (other

8. Krishnan T N. The Role of Agriculture in Economic Development. [Ph.D. thesis,] MIT, 1964.

nutrients) or both might increase. The important aspect that one has to consider, is that if difference between the open market and issue prices is wider for non-staple commodities it may have undesirable results. For example, if milk was supplied in ration, for the poor at a cheaper rate, the chances of it being resold by the poor to other groups are high, in order to increase income. If so, the purpose of subsidy improvement of the nutritional status will be lost. Therefore, the issue is one of choosing such of those commodities for subsidy as have strong preferences among the target group of population. After estimating the demand for various selected commodities, one can examine the impact of changes on issue prices and on incomes with reference to consumption. Subject to the availability of data, this should be useful for policy purposes to determine pricing policy.

It is useful to investigate the compatibility between the nutrition composition of various items and the corresponding price structure. This would provide insight into the rationality of the existing pricing (market or institutional), both in regard to production system (in terms of procurement prices) and consumer system (issue prices in public distribution). It is possible that because of preferences, and traditional factors governing the consumer behaviour, the compatibility sought for may not prevail. However, the observed deviations may be helpful in formulating appropriate support price mechanisms both in respect of producer and consumer systems. For example, a superior variety with nutritional composition of a commodity can be procured by the government at a reasonably higher price so as to encourage its production.

A theoretical approach for testing the compatibility between prices and nutritive values for different types of commodities is presented below. An insight into these aspects would enable the policy-makers to formulate a rational relative pricing policy.

Testing Consistency of Price with Nutritive Content

First, we test the preservation of ranking of price over time and then test whether the price structure is consistent with nutritional content. Let us consider some varieties of rice, say 'n' and their prices for some years, say 'm'. Then rank the prices of these 'n' varieties for all the 'm' years. For purpose of illustration the table below may be seen.

Period Varieties of rice	Prices of different varieties of rice				Ranks of price data relating to different varieties of rice		
	1	2	3	4	1	2	m
V_1	P_{11}	P_{12}	P_{13}	P_{1m}	R_{11}	R_{22}	R_{2m}
V_2	P_{21}	P_{22}	P_{23}	P_{2m}	R_{31}	R_{12}	R_{3m}
V_n	P_{n1}	P_{n2}	P_{n3}	P_{nm}	R_{n21}	R_{n2}	R_{mn}

Assuming that there are no market distortions, and preference and tastes do not change significantly, one would expect that ranking will be preserved over time.[9] To test the variations in the ranking pattern, we can consider *Spearmen's rank correlations method*.[10] The hypothesis to be tested in that ranking has been significantly changed over time against the alternative hypothesis that there is no significant change in the ranking.

9. The market distrotions can influence the ranking over periods. For instance, restrictions on trade and movement can influence the price structure. In such situations the effects of these have to be isolated, i.e., one has to determine the price level, had there been no restrictions regulations of the sort mentioned above. With the revised price series, the analysis should be carried out.

10. See, Xendall, M. C. Rank Correlation Methods. Charles, Griffin, 1970.

To test the hypothesis, the test statistic W, coefficient of concordance, will be computed and tested for its significance.

The co-efficient of concordance is given by

$$W = \frac{12\,S}{m^2\,(n^3 - n)}$$

where m = no. of years
n = no. of varieties of the commodity
s = sum of squares of deviations

To compute S, the following procedure is followed. Sum the ranks pertaining to each variety of rice in different time periods. Let these values be $S_1\ S_2 \ldots\ldots S_n$ and the mean of these sums be $\bar{S}$.

$$\therefore\ S = \sum_{i=1}^{N} (s_i - \bar{s})^2$$

In case some rankings contain ties,

$$W = \frac{12\,S}{m^2\,(n^3 - n) - 12m \sum_{T'} T'}$$

where T′ takes places over the various rankings

and $T' = \frac{1}{12} \sum_{t} (t^3 - t)$

A value of W close to 1, indicates a greater measure of agreement in the rankings. To test the significance of W, consider the following statistic, which follows a chi-square distribution, with (n-1) degrees of freedom (for n>7).

$$m\,(n-1)\,W - X^2 \quad n-1$$

i.e. $$\frac{12\,S}{mn\,(n+1)} \quad \sim \bar{C}^2 \quad n-1$$

If the observed value is higher than the tabular value we reject the null hypothesis in favour of the alternative.

In the second stage, that is, once the ranking of price data has not changed over time, one has to compute the rank correlation between the nutritive content and price of different varieties of rice. Since the nutritional content is a vector, one has to transform the vectors into scalers, in order to rank the different varieties of rice. In general, scalarisation will pose some problems One can use the marginal costs of obtaining different nutrients (derived separately) as weights taking the weighted average to arrive at a scaler value of different varieties of rice. Methods of scores [11] can be used to obtain the rank correlation of the series (one ranking according to nutritional content and the other ranking according to price level).

Rank correlation coefficient, $\bar{C}$ is given by

$$\bar{C} = \frac{\text{Actual score}}{\text{Max. possible score}} = \frac{S}{\frac{1}{2}n\,(n-1)} = \frac{2\,(P-Q)}{n\,(n-1)}$$

Where S = total score
P = positive score
Q = negative score
n = no. of varieties

Positive correlation indicates consistency of price structure with nutritional content. Value nearing zero is indicative of independence. Negative correlation co-efficient represents inconsistency. However, nutritional unawareness, local availability demand/preferences market distortions, etc. can influence the prices and therefore deviations from an unexpected level (consistency) of price with nutrition composition can be expected.

11 See Rank correlation methods by M G Kendall. Charles Griffin & Co. Ltd., 1970 (4th edition)

We have so far attempted to examine the implications of the various components of prices policy. More formally, these could be incorporated in the integrated models governing the production and consumption systems in terms of these and other particulars. These formulations are of use in helping the policy planners to examine the sensitivity or impact of these sub-components on the food policy.

Since a few other important components of the food policy like buffer stock operations, inter-zonal movements, and procurement policies contribute directly and indirectly to the price of foodgrains and highest price of different nutrients it is useful to examine the role of some of these components in addition to the direct impact of price element on nutrition intake.

2.3 Procurement

Some of the main features of the procurement policy are: (1) the commodities—some specific varieties of these—to be procured, and (2) the quantities to be procured and their corresponding prices. These will significantly influence, both production and consumption. By confining the procurement operations to certain commodities or some varieties of these commodities, the production pattern can be influenced in favour of these items. Generally; the commodities to be procured can be either (a) those having high nutrient supply, or (b) those having demand and high prices in the world market irrespective of nutrient content, or (c) have significant use for mass consumption, particularly by the poor. In the case of (a), that is, procuring some specific varieties (if necessary at a higher price), these will be encouraged most for the production of these varieties. The choice of (b) is justified, because the export of these items will, in turn, benefit the society by importing or equivalently subsidising in public distribution system to obtain more nutrients. In the case of (c), it is not proper to expose the low-income groups to the fluctuating market behaviour; and hence

the operation of this step coupled with an efficient public distribution system would ensure proper nutritional status for this class.

Procurement together with the system of public distribution can influence dietary habits too. During this decade the wheat consumption in the Southern States has increased as can be seen from Table 2. It shows some positive correlation between procurement of wheat from the producing States and the consumption in non-wheat growing States.

Table 2 : Net Availability of Wheat in Different Southern States ('000 tonnes)

Year	A. P.	Tamil Nadu	Kerala	Karnataka
1960-61	13.4	90.0	–	132.2
64-65	133.9	176.4	8.0	205.7
68-69	127.6	214.4	58.0	363.6
70-71	120.0	337.4	58.0	295.2
72-73	173.5	239.4	84.0	343.0
73-74	401.2	284.1	360.0	664.1
74-75	251.1	174.4	324.3	534.3
75-76	291.2	683.5	596.3	551.5
76-77	197.7	265.5	271.7	387.2
77-78	155.0	433.0	255.0	468.8
78-79	186.0	464.0	165.0	520.2

Source : Bulletin of Food Statistics, 1980.

The quantity procured should be determined in the context of the (i) desired price stability as may be affected by buffer stock operations, (ii) commitments for public distribution, and (iii) plan targets to raise consumption level of the poorer sections. At present, there seems to be some discrepancy in operation between (ii) and (iii).

We recognise that the quantity procured and the procurement prices have an impact on production (and also consumption). The optimal policies of reserving commodities to be covered for governmental procurement along with the quantity and price specifications can be derived after formulating models governing production and supply of nutrients (for different classes of producers, if need be) in terms of these variables among others. However, there are other intervention mechanisms like guaranteed price scheme, crop insurance, etc, which also have significant impact on production in that they reduce the risk factor governing the behaviour of producers.

The determinants of quantities of procurement of rice and wheat are examined in a previous study and the results are given in the following paragraphs. These differ from State to State but, as a comprehensive list, they seem to be confined to secular time trend component, production of rice/wheat in a given State and production of cereals in the country as a whole in a given year, deviations in production with respect to expected trend value and changes in political leadership. The procurement policy does not take into account its nutritional implications via changes in market prices and availability.

A general model for rice and wheat procurements is given below :

$$P = a_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 + b_6 x_6 + b_7 x_7 + u$$

where, P = Procurement of the commodity (rice/wheat)

x_1 = Production of the commodity in the given State in the given year

x_2 = Absolute deviations of the all-India trend in production of cereals from the actual all-India cereals production in the given year.

Estimate Regression Equations for Rice Procurement
(Dependent variables Rice Procurement)

Sl. No.	State	Constant	X_1	X_2	X_3	X_4	X_5	X_6	$\bar{R}^2$	R^2	S.E. of the estimated value	D.W.	No. of observations
1.	Andhra Pradesh	-4.053				0.630 (1.93)	-0.541 (1.63)	0.335 (3.91)	0.60	0.72	0.11	2.01	11
2.	Assam	0.011		-0.004 (1.73)		0.0404 (2.32)			0.49	0.59	0.02	1.90	11
3.	Haryana	-0.160	0.909 (8.07)				0.039 (0.64)		0.90	0.93	0.09	2.94	8
4.	Madhya Pradesh	-0.586		0.021 (1.56)		0.097 (3.01)			0.42	0.54	0.11	0.87	11
5.	Orissa	0.133		0.007 (1.30)	0.002 (0.34)			0.104 (2.03)	0.33	0.53	0.06	2.28	11
6.	Punjab	0.069		0.007 (1.35)	0.042 (6.24)				0.87	0.91	0.04	2.71	8
7.	Tamil Nadu	-0.490	0.168 (1.02)				-0.271 (0.97)	0.535 (4.25)	0.84	0.89	0.12	2.50	11
8.	Uttar Pradesh	-0.266	0.104 (8.60)		0.018 (6.70)		-0.015 (2.22)		0.94	0.95	0.24	2.60	11
9.	West Bengal	-0.479	0.130 (1.43)	0.009 (0.67)	-0.018 (1.37)			0.162 (2.22)	0.28	0.57	0.11	2.48	11

Note : The figures in the brackets refer to 't' ratios

Source : All India Grain Storage and Distribution Study, ASCI, Hyderabad, 1978.

Estimated Regression Equations for Wheat Procurement

(Dependent variables : Wheat Procurement)

Sl. No.	State	Constant	X_1	X_2	X_3	X_4	X_7	$\bar{R}^2$	R^2	SE of the estimated value	D.W.	No. of obs-r-vations
1.	Haryana	-0.105		0.0007	0.169	-0.074	-0.416	0.96	0.98	0.06	2.40	8
				(1.04)	(7.56)	(1.17)	(4.20)					
2.	Madhya Pradesh	0.172	-0.083	-0.008	-0.018			0.84	0.68	0.04	1.94	11
			(2.60)	(1.97)	(3.60)							
3.	Punjab	-1.475	0.406	-0.002	0.063		-0.702	0.90	0.99	0.15	3.02	8
			(2.93)	(1.18)	(5.02)		(3.02)					
4.	Uttar Pradesh	0.667		0.028	0.216	-0.112	-0.603	0.66	0.83	0.24	2.53	11
				(1.01)	(2.901)	(1.42)	(1.50)					

Note : The figures in the brackets refer to the 't' ratios.

Source : All India Grain Storage and Distribution Study, 1978. ASCI, Hyderabad.

X_3 = Trend variable

X_4 = Production of cereals in the year t

X_5 = Deviations of the trend production of cereals from the actual production in the year t in the State

X_6 = Dummy variable which takes the value unity (zero otherwise) P has changed because of changes in parties in power in the given state

X_7 = Dummy variable which takes the value unity (zero otherwise) if procurement belongs to 1973 and 1974 (This is with respect to wheat only)

u = Disturbance term.

2.4. **Public Distribution***

Some of the important issues of public distribution policy are : Commodities to be distributed and to which sections, quantity to be supplied to the various groups, prices to be charged for different classes of society and the mode of distribution.

If we generalise the concept of public distribution system to include the feeding programmes for school and pre-school children of low income groups, etc, we have to examine the optimal combination of different intervention spheres, given the costs of meeting certain types of nutritional deficiencies in different regions and age-groups, priorities in view of long-term effects of nutritional deficiencies and effectiveness of these schemes. The discussion in Chapter 2 of this report reveals that top priority, irrespective of region, cost, etc, should be given to pre-school children and pregnant and lactating women. Some measures like fortification of foods with specific preferred nutrients; processing and preserving of

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* Special nutritional programmes are also a part of the public distribution system to increase nutrition status of vulnerables and have to be discussed separately.

foods to make even the availability across regions and in different periods are also necessary. In order to evolve specific programmes in this direction the identification of the nature and extent of nutritional deficiencies in different regions according to appropriate classification of the population is needed. With this information, it should be possible to arrive at a combination of factors in terms of commodities to be covered by the public distribution system, other supplementary programmes like fortification and quantities at which these are to be supplied.

The nutrition gaps in different sections of the society in various parts of the country have not been the considerations for determining public distribution of foodgrains through Fair Price Shops (FPS). Increases in urban population in different States have been contributing to the increasing demand for public distribution. The volume of public distribution work in most States has suddenly gone up in the pre-election year 1966, with the exceptions of Punjab, Gujarat, and U. P. The all-India distribution showed a jump from 101 lakh tonnes of cereals in 1966.

The behaviour of quantities of public distribution of rice and wheat in various States is explained mainly in terms of secular trend component, production with respect to expected trend production and election periods. The econometric regression relations are shown in the following pages. It is clear that the nutrition gap factor is yet to make its impact on the policy governing public distribution of foodgrains.

Estimated Regression Equations for Rice Issues

(Dependent variable : Rice issue)

Sl. No.	State	Constant	X_3	X_4	X_5	X_8	$\bar{R}^2$	R^2	S. E.	D.W.	No. of observations
1.	Haryana	0.068		-0.008 (5.53)	0.001 (.024)	-0.014 (2.40)	0.85	0.91	0.01	2.46	8
2.	J & K	-0.003		0.088 (5.90)	-0.069 (5.01)	0.005 (1.24)	0.77	0.84	0.01	1.60	11
3.	Kerala	-0.873		1.276 (3.62)	-0.671 (1.30)	0.386 (4.10)	0.64	0.75	0.09	1.12	11
4.	Madhya Pradesh	-0.298		0.046 (1.90)	0.078 (2.72)	0.004 (0.12)	0.46	0.62	0.04	0.55	11
5.	Orissa	-2.413		0.590 (3.90)	-0.66 (4.11)	0.020 (0.69)	0.70	0.79	0.03	1.30	11
6.	Tamil Nadu	-2.140		0.440 (0.70)	-0.980 (1.14)	0.100 (0.54)	0.21	0.44	0.28	1.34	11
7.	Maharashtra	1.616		-0.241 (1.66)	0.269 (1.82)	0.190 (5.70)	0.77	0.84	0.04	0-87	11
8.	Uttar Pradesh	-0.263		0.031 (3.24)	-0.051 (3.50)	-0.063 (1.61)	0.51	0.66	0.05	1.90	11
9.	West Bengal	-0.682		0.190 (3.70)	-0.080 (0.090)	0.219 (2.5)	0.72	0.80	0.11	1.54	11
10.	Delhi	0.005	0.032 (3.40)	-0.001 (2.92)			0.49	0.59	0.01	2.00	11

Note : 1. The figures in the brackets refer to 't' ratios.

2. For Delhi the variables X_3 and X_4 are urban population (not time and all India all cereals production respectively.

Source : All India Grain Storage and Distribution OPCT. Supporting Study 5, Table 8 of Appendix 1956.

Estimated Regression Equcations for Wheat Issues

(Dependent variable : Wheat issues)

Sl. No.	State	Constant Term	X_3	X_4	X_5	X_8	$\bar{R}^2$	R^2	S.E.	D.W.	No. of observations
1.	Assam	0.200	0.007 (0.91)	-0.064 (1.04)	0.083	0.083 (3.67)	0.53	0.67	0.03	2.37	11
2.	Haryana	-0.101		0.060 (2.03)	-0.057 (1.24)		0.24	0.46	0.04	2.00	8
3.	Jammu & Kashmir	-0.015		0.129 (3.92)	-0.259 (4.07)	0.055 (3.69)	0.74	0.82	0.02	2.79	11
4.	Karnataka	0.021	0.022 (1.10)		0.006 (0.33)	0.?3 (4.61)	0.70	0.79	0.04	1.64	11
5.	Kerala	1.341	0.021 (0.93)	-0.992 (1.87)			0.20	0.36	0.14	1.75	11
6.	Madhya Pradesh	0.067	0.005 (0.40)	0.022 (1.00)		0.138 (1.40)	0.10	0.37	0.12	1.40	11
7.	Orissa	0.072	0.007 (2.20)		-0.045 (1.70)	0.012 (0.40)	0.40	0.50	0.03	2.50	11
8.	Punjab	0.474	0.045 (3.58)		-0.075 (3.35)	-0.055 (1.52)	0.74	0.85	0.03	3.50	8
9.	Maharashtra	0.069		0.171 (0.29)	0.202 (0.34)	0.323 (1.41)	0.44	0.60	0.17	1.96	11
10.	West Bengal	-0.834	0.296 (2.91)	-0.211 (2.10)		0.297 (2.42)	0.42	0.60	0.16	2.44	11
11.	Delhi	0.260	0.323 (7.60)	-0.012 (6.54)	0.006 (1.48)		0.86	0.90	0.03	1.24	11

Note : 1. The figures in the brackets refer to 't' ratios

2. For Karnataka, West Bengal and Delhi X_3 is urban population (not time trend)

3. For Delhi x_4 is All India cereals production and X_5 is deviations from observed to fitted of All India Cereals Production

4. Source : All India Grain Storage and Distribution, Supporting Study 5, Table 9 of Appendix.

The following general model is formulated for the estimation of regression relations :

$$D = a_0 + b_1x_1 + b_3x_3 + b_4x_4 + b_5x_5 + b_8x_8 + u$$

Where, D = Public distribution quantity of given commodity (rice/wheat) in a State at time 't'

x_1 to x_5 = As given in 2. 3

x_8 = Dummy variable which takes value unity if the observation D_t belongs to the immediate pre-election year in the given state and value 'O' otherwise

u = Disturbance term.

Deficiency has been identified as the major nutritional problem in India. The calorie gap can be reduced by supplying calorie foods in adequate quantities at a price within the reach of the poor. As regards choice of commodities, since a majority of the nutritionally vulnerables belong to the poorer sections of the community, public distribution should aim at supplying those commodities to the poor, which will gradually close the nutrition gap. For instance, 'calorie' purpose, will be served by either cereals or tuber and roots or both. The next step is the cost of deriving one unit of calories (say, 1,000 calories) from these sources. For instance, to get 350 calories one needs either 100 gms of rice/wheat costing around 10 to 14 paise or about 400 gms of potato which costs about 40 paise (in the case of potatoes, the cost of preservation, transport, etc, to public authorities/traders is generally higher). Therefore, public distribution can either provide more calories by increasing the quota of the major cereals[12] or by supplying the present quota at a lower price, whereby one can meet one's needs through open market supply. This may result in more expenditure to the State exchequer by the increase of subsidy by a few more crores, but if it bridges the

12. In the regions where the present ration quant ty meets calorie needs policy instrument that can be effective for nutr t onal intervention is the price.

calorie gap the net gain in real terms will be significant. An analysis of costs and benefits would reveal that the benefit–cost ratio is very high if we consider the benefits like (i) better nutritional status which leads to higher productivity particularly in the low income earning working class, (ii) reduction in public expenditure on health, (iii) increase in the span of productive life, and (iv) rise in the standard of living and mental development Let us consider a case to study the impact of subsidy on the intake of nutrients. In 1974, about 10.80 million tonnes of cereals have been issued through public distribution system (fair price shops/ration shops) covering nearly 4,313 lakhs of population.[13] So, the average per capita quantity of cereal issued per day amounted to 68.5 gms yielding approximately 240 calories and 8 3 grams of proteins. Assuming an individual demands/consumes on the average 400 gms of cereals (ICMR nutrition norm for sedantary workers), we attempt to find the expected increase in nutrient intake as well as additional cost to the State exchequer for various levels of subsidy on the basis of price elasticities. The price elasticities for cereals have been presented in Table 3.

Table : 3 Price Elasticities of Cereals

Region	Price elasticity
Rural	–0.35
Urban	–0.5
All India	–0.38

Source : Krishnan T N. : The role of agriculture in economic development, [Ph. D. Thesis], MIT, 1964.

Assuming on an average weightage[14] that the issue price is Rs. 150 per quintal of cereals, the net gains in terms

13. *Bulletin on Food Statistics*, 1966, pp. 29, 50.
14 Weights are proportional to quantity of different cereals issued

of calorie and protein intake for different levels of subsidy and the associate cost to public authority are presented in Table 4.

Table 4 : Net gains

Extent of subsidy (% price fall)	Additional cost to State exchequer (in crores Rs)	Expected increase in consumption (gms/day)	Increase in intake Calories	Proteins (gms)
10%	161.85	15.20	53.2	1.5
15%	242.78	22.80	79.8	2.3
20%	323.70	30.40	106.4	3.0

Exercises like lifting people be'ow nutritionally defined poverty line (as suggested in Draft Five–Year Plan 1978-83) will be better done by examining the sensitivities with reference to price/income as depicted above. The above type of empirical investigations would enable the policy-makers assess the likely beneficiaries and magnitude of benefits under different intervention costs. Assuming that price elasticity of demand for food items in rural Tamil Nadu, say, -0.38, the implications of different food subsidy levels, for different expenditure groups, in terms of calorie intake can be studied. For example, reducing issue price by 20 per cent will increase the daily average intake of calories from 1778 to 1884, for the persons in the expenditure group 18-21.[15]

In the past, the governments did not draw any distinction between rich and low income groups in the case of informal rationing (i. e. ration quantity) in many States. But such distinction is essential in respect of the commodity coverage, quantity and price.

The mode of distribution may be either statutory or informal rationing or fair price shops. According to ICMR balanced diet (1968) an adult should consume nearly 16 ounces

15. Rajagopalan S. Seasonal dimensions of rural poverty. *Tamil Nadu Nutrition Project-A Case Study*, July 1978.

of foodgrains every day. Under statutory rationing, the vulnerable should get certain amount of nutrients in terms of foodgrains. But, in the past, the quantity of cereals supplied was varying, and in bad years it was nine ounces. In the other modes of distribution, the quantum of issue is uncertain and is related to the stock level.

One of the present problems is the non-existence of a systematic distribution system to cover rural areas. In respect of rural areas, it was suggested that fair price shops should be particularly opened in the lean periods when the nutritional intake by the poor will be at its nadir. The requirements as well as intake of individuals will be varying due to seasonal factors, particularly in rural areas. The fluctuations in wages will lead to changes in food intake and if the nutrient intake(s) fall below the critical level for a reasonably long period, its impact on the efficiency of the human mechanism will be adverse. Rajgopalan[16] attempted to present the consequences of seasonal fluctuations on nutritional intake and factors like morbidity and mortality. However, a more systematic and rigorous analysis will provide better insight into this matter.

Nutrition-gap-oriented public distribution system will have an important role in reducing the nutrition deficiencies. Such a system would require identification of the magnitude by each of nutrition gaps (e.g. x units of calories, y units of vitamin A, etc) in different regions (like blocks/taluks/districts) with reference to different categories of population (age groups/socio - economic - occupational groups etc.) seasonwise (e.g. in case of agricultural labour off-work seasons). Obviously, such an exercise has to rely heavily on availability and processing of relevant information. Unless

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16. Rajagopalan S. Seasonal dimensions of rural poverty, *Tamil Nadu Nutrition Project - A Case Study, July 1978.*

a systematic effort on these lines is made in addition to various other direct and indirect nutrition intervention strategies, it would be difficult to minimise the nutrition gap.

2.5 Imports/Exports

From nutrition point of view, one has to consider what food items are exported/imported and how much quantities have entered into trade and/at what prices? India has been trading in several food items, such as foodgrains, oilseeds, sugar, fish, etc, and the long-term trade agreements in these commodities will have nutritional implications via price and availability of these commodities in the home market. If nutritious food items were exported when the world market prices are lower than domestic market prices or when the revenue earned through export of food items was not reinvested in the food imports the nutritional impact will be negative.

India can follow the export policy of some of the Asian countries, such as China and Taiwan by exporting commodities, such as basmati rice, to nations, like Egypt, Saudi Arabia, etc, and import those items which are relatively cheaper and provide more nutrients. The present policy of banning export of fruits and vegetables will improve the supply position of nutrients. This ban should be extended to items like edible oils, fish etc, for some time to come, unless the export prices are very remunerative and revenue earned from food exports is reinvested in food imports.

The importers of staple foods, in periods of scarcity, will not only improve the supply position but also check the price rise in the domestic market.

2.6 Buffer stocks

The basic principles underlying the operation of buffer stocks are to: (a) meet the demand arising out of public distribution, and (b) regulate the undue and unwarranted price

fluctuations in different periods. The size of the buffer is a function of public distribution commitments and the tolerable instability in price levels. The direct impact of buffer stocks on nutritional status is through procurement, movement and distribution operations, which in turn are effective through resultant price level. The indirect impact is that buffer stocks reduce the speculative element to a significant extent.

So far the government's buffer stock operations covered foodgrains, oilseeds, etc. It may be argued that buffer operations should be extended to supplementary and protective foods. If the objective of the public authorities is to supply these nutrition foods, to the vulnerables, one has to consider the economic implications of the existing alternatives. For example, one has to look into cost of supplementation Vs. costs of fortification. The nutritional dimension of these buffer operations should be assessed through cost implications as well as the increase in nutrient intake by the needy.

The Statewise distribution of the central pool food stocks is not necessarily related to a set of objective criteria based on the administrative/politically determined demand for food in States and available stock position in the central pool. Narayanan and Prasada Rao[17] concluded after analysing Central pool operations during 1970-76 that: "the operation of central pool of cereals was not able to ensure a more balanced distribution in the country; the States could not make up their deficiencies with allocation from the central pool; the allotmenr from the central pool is not governed by the actual needs of different States".

2.7 Trade Regulation/Zonal Restrictions

Whether trade regulations are effective in improving the supply of nutrients to the vulnerable groups, is an issue of

17. Narayanan S, Prasada Rao D V L N V. Cereals and the Central pool. *Eastern Economist*, June 1, 1979.

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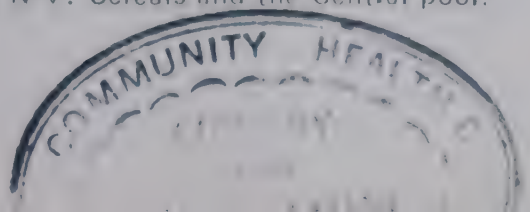

special importance. However, the nutritional implications of trade controls to the extent they uffect the production and consumption (with respect to the commodity under consideration in both the surplus and deficit regions, can be studied through price implications of different regulations cosidering the cost of enforcement of these regulations/interventions. It was observed that trade regulations adversely af'ect the producer in surplus regions and consumer in deficit regions and benefit the consumer in surplus region through increase in the availability and price fall and producer in deficit areas by providing a higher price for his produce. One should be wary regarding trade regulations, since they could affect the interests of producers adversely and if so could result in (fall of) reduction of nutrient supply in future. In periods of scarcity, it is quite likely that trade regulation can affect the consumer in the deficit areas in the absence of government intervention. The choice of a particular mode of regulation or intervention depends on the policy of public authority and the operational costs involved.

An alternative to the trade restrictions in free trade which is more efficient, but it does not ensure equitable consumption across the regions, even in periods of surpluses. It was observed that there were wide disparties in calorie intake in 1961-62 when embargo on movement was lifted, since the price differential did not provide an incentive for reducing the inequalities in calorie intake. In India, the trade regulations are confined to commodities, such as cereals, oilseeds, etc, which are nutritionally important items. However, trade regulations should be accompanied with public intervention programmes, such as intensive procurement in surplus areas, distribution of these to vulnerables both in deficit and surplus regions, etc.

The implications of free or regulated trade on the aggregate food supply as well as its composition have to be

studied in detail. It has been argued by Gale Johnson[18] that under free trade in product and input markets of agricultural sector, the world food production was maintained throughout the decade. A study of FAO (1971)[19] derived the conclusion that food supply under free trade would be slightly higher than that with 1970 farm prices and policies. There has been strong contention that free trade policies will divert the production pattern in favour of the rich through price elasticity. At the global level, one of the probable outcomes of free trade policy is that use of foodgrains as a livestock feed will increase and consequently the poor may be deprived of adequate nutrient intake. Though this policy will increase earnings of the poor nations through expansion of export markets, an increase in farm output is a necessary condition for acceptance of such a policy from nutrition point of view. The effects of trade policies will have to be studied in terms of consumer prices and consumption levels in different regions. The demand for different food products, such as foodgrains, flesh foods, etc, in different regions depend upon price elasticities of these products. In the case of free trade, demand for flesh foods would increase and this would in turn result in a higher proportion of grains to be used as livestock feed.

Kahlon and Anlakh (1978)[20] analysed the price data relating to three major foodgrains of Punjab (wheat, gram and maize) for the period 1960–69 to find the impact of trade

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18. D Gale Johnson. Free trade in agricultural proudcts: possible effects on total output, prices, and the international distribution cf output. *In* G. S. Tolley, & Peter A Zadrozny. *Eds, Trade, Agriculture and Development*. Ballinger, Cambridge Mass. 1975

19. FAO Committee on commodity problems. A World Price Equilibrium Model. CCF 72/WP, 3, Rome.

20 Kahlon A S. Anlakh M S. The role of zonal policy in creating an imperfect market structure in the Punjab. *Indian Journal of Agricultural Economics vol*. 1978, 33(1)

regulation on regional price differentials. The coefficient of variation of prices under different zonal policy periods in producing consuming and terminal selected markets, computed by them are presented in Table 5.

Table 5 : Coefficient of Variation of Price under Different Trade Regulation

Grain	Free Trade	Multi–State zone	Single State zone
wheat	9.86	10.85	23.8
Grain	4.34	11.05	19.14
Maize	1.64	9.70	8.17

From this table, it is evident that coefficient of variation of prices of foodgrains are lowest where there were no restrictions on movement of foodgrains on private account.

The price differentials and transport costs reported by traders in the selected markets under different zonal policy restrictions for wheat were also computed and is shown in table 6.

Table 6 : Price Differentials

Market	F. T.		M. A. Zone		S. S. Zone	
	Price dif.	T.C.	Price dif.	T.C.	Price dif	T. C.
Khanna-Bombay	14.81	9.82	3.25	9.50	15.68	10.15
Khanna-Hapur	0.74	7.05	7.74	6.70	32.44	8.18
Khanna-Khagaria	8.36	8.56	16.64	8.37	51.22	9.90

The price differentials are the lowest in the absence of zonal restriction and price differences over and above transport costs can be attributed to zonal restrictions. Trade regulations, it has been observed, have created imperfect markets. However, the actual quantum of these grains moved to other markets and available for domestic consumption in Punjab markets are needed to study the impact of zonal restrictions on supply/consumption of grains in both surplus and deficit regions.

Findings and Recommendations

1. a) Historically, food policy emphasised on the quantity dimensions of food consumption; this was consistent with the chronic state of shortage of foodgrains in the country till about four years ago. Until the Fourth Plan, explicit recognition could not be accorded to nutritional aspects of food policy probably mainly due to shortage of foods in terms of quantity.

(b) Even after incorporating the nutritional dimensions of food policy in the Five-Year Plans commencing from the Fourth, it is apparent that concerted effort was not made to progressively eliminate nutrition gap. A number of schemes are operated by a number of departments simultaneously in different areas in the country: there seems to be no systematic pattern in identification of priorities in terms of geographic location and target groups for nutritional development, with the result that scarce resources are thinly spread. At present, the nutrition sectors stands as a residual component in the Five-Year Plan formulation.

(c) Separate studies have indicated the long-term social benefits of betterment in nutritional status of vulnerable groups of the society (especially children) and on those grounds, high priorities needs must be assigned to this sector.

2. Pricing policy, especially procurement prices for food commodities and relative prices of different varieties of food commodities, has to be carefully designed to encourage increase in effective nutrient supply at the farm production level; this can be done by evolving prices in favour of nutrient rich commodities/varieties within specific commodities.

3. Public distribution system has to be established and strengthened and should have the following aspects carefully incorporated :

(i) The areas for constant public distribution of foodgrains need not be concentrated only in urban areas; priority should be given to those pockets in which significant nutrition gaps are identified.

(ii) The pricing of food commodities through the public distribution system should be the reverse of the policy suggested for procurement, namely, lower price for commodities which have greater relevance to bridge the nutrition gap (by increasing the effective consumption at lower prices).

(iii) Coverage of food items should be more comprehensive so as to supplement the nutrition requirements in different areas more effectively; the list of items to be covered and the quantities to be distributed have to differ from one region to another depending on the assessed nutrition gaps - in magnitude and type.

(iv) There should be a long-term policy of commitment regarding distribution of foodgrains with the aim of progressively reducing nutrition gap partially; the portion of the gap that needs to be eliminated using this intervention mechanism should be arrived at after assessing the existing magnitude and type of nutrition gap and the estimated impact of other direct and

indirect inrervention strategies (like rise in real incomes, changes in relative prices, health facilities, and preventive medicine, nutrition education, etc).

(v) Special categories of food items catering to specific age groups, especially children, must be channellised through a distribution network in order to reduce long-term costs of mal-nourishment to the society; similarly, on a priority basis whenever drought situation or other seasonal and periodic shortages occur, necessary augmentation in the food suppliers should be made, particularly to meet the increased nutrition requirements of pre-school children and pregnant and lactating women. The experience of, and subsidy scheme for, pregnant women in countries like U.K. may be relevant and should be carefully examined.

4. The state of knowledge is thoroughly inadequate to prescribe the minimal nutrition requirements for different types of individuals. Also, the alternatives suggested by some for correcting the traditionally used specifications of nutrution requirements are based on weak foundations and are unacceptable for the purposes of policy planning and aimed at betterment of nutritional status of the affected sections of the society. The estimation of magnitude of poverty can at best be guided only partially by the nutrition norms. Further research work on relevant issues in nutrition science is urgently called for.

5. Poor are not attached to inferior cereals/millets because of palatability or things like that. Their menu is mainly affected by price mechanism. The issue in production system is how to maximise the quantity and quality of nutrients per unit land per season in a least-cost manner. The need to activate inferior cereals (as suggested by some) production should be selective, and these may not be produced (unless HYV varieties are brought in) at the expense of cereals.

6. Improving the network of dairy farms will enable the proper distribution of milk. Apart from this, animal husbandry schemes have been introduced to ensure the optimum (improved) yield and better health to the animals. Following Anand pattern, and adopting the cross-breeding programme of animals, it is worthwhile to develop milk production as a subsidiary industry in rural areas. The programme should be aimed at small and marginal farmers by giving the necessary facilities in view of lack of purchasing power in lower income groups in rural areas as this generates employment also.

2

Integrated Nutrition Planning Models

1

Introduction

One of the principal objectives of social and economic development is to raise the living standards, especially, of the poor and the under-privileged. Very often, not entirely without justification, the average per capita income is considered as a good measure of the living standards. By and large, increases in consumption (on the part of the poor) take place only with an increase in their average income whether this income accrues to them directly or in some other way. Since expenditure onitems of food claims a major share of the income of the poor and as a corollary whenever there is an increase in income, followed by an increase in consumption expenditure, their food consumption is expected to go up. This progress, however, does not always ensure that the poor will,with an increase in their income, demand or wil get the diet that contributes to their better nutritional status/health. We may, therefore, conclude that increases in income of the poor is a necessary condition, not sufficient enough to provide them all the nutrients that will be adequate for their health and work, and also for the satisfactory growth of their children. The presence of malnutrition even among the betteroff sections of the society is an additional piece of evidence of support of this proposition.

If an increase in income is only a necessary condition for reducing malnutrition, especially among the poor in the country, it becomes necessary to explore other supplementary measures that will improve the nutritional status. These measures can be put under two broad categories: On the one hand, we have those that influence the nutrient content of foods that are made available to the community at reasonable

prices and are sufficient to meet their needs and, on the other, given the behavioural pattern of the consumers, incentives can be given to generate a pattern for demand that will be consistent with the nutritional requirements of the consumers. In other words, the policies should aim at an increase in the supply of nutrients or nutritious food not only at the national level but also for the various segments of the country at reasonable terms and supplement them with a programme where the buying habits of the population are so moulded that their consumption of essential nutrients will not be too far removed from their actual needs. Also, non-nutritional factors like infection, pollution, etc, which have bearing on nutritional status should also be integrated with nutritional system and its analysis. This, in brief, is the scope of this study.

There are a number of studies, in India and abroad, dealing with various facets of the nutritional problem. Many of them pay attention to the physical and mental deficiencies, particularly the incidence of various diseases and explain them in terms of their inadequate intake of calories, proteins and various other nutrients. A high rate of infant mortality, low body resistance to various viruses and retardation of mental growth, etc, are due partly to the inability of the pregnant mother to obtain satisfactory diet together with unsatisfactory feeding of the young. The height, weignt, shape and size of the limbs and levels of development of various mental faculties of the infant can also be attributed to the less than adequate intake of various nutrients from the state of pregnancy to the early childhood. Even among the grown-ups, the low intake of calories and proteins, according to a number of these empirical studies, explains their fatigue and low performance. All these studies are not quantatitive; a number of them are vigorous only to suggest the qualitative estimates of the various nutrients that will prevent the occurrence of most of the deficiencies.

Some studies go a few steps further to explain the low intake of nutrients. These studies showed that income alone

was not primarily responsible for the low intake of nutrients, social habits and prejudices, and even knowledge about nutritious foods. in more general terms throw sufficient light, on their consumption behaviour in respect of nutrients. In this area, some recent studies have attempted to assign quantitative relations for a number of explanatory variables, such as income, family size, sex, caste, education, infection, etc, which have influence on the intake of some of the principal nutrients, such as calories, proteins, etc.

Supply Side

The supply side of the nutrient problem has also been receiving increasing attention in the development of new strains; researchers are looking into the nutritional content of these strains and at different levels the fortification of available foods with various nutrients is also gaining importance. Alongside these analytical studies, extensive discussion of various programmes designed to meet the nutritional deficiencies is taking place. These discussions are not confined to the fortification problem alone. The supply efficiency and economics of various nutritional foods through various institutions meant for maternal and child care are turning out to be the principal areas of investigation.

All these studies, as is obvious, have had a limited objective Some are purely analytical without incorporating the implications of the various public policies, general as well as specific, to nutrition. They are not integrated into a total system to be able to help in formulating a national nutrition policy. The Tamil Nadu Nutrition Study aims at collecting comprehensive data relating to the principal sub-systems—production, processing,and consumption-which constitute the totality of the nutritional system. In any comprehensive study of this nature where the aim is to collect data on various constitutent sub-systems, it is necessary to have a broad theoretical framework. This theoretical frame work should not only

incorporate the principal variables and their structural relationship, but should also include the policy variables in a meaningful way so that the impact of policies on various desired objectives could be thoroughly investigated.

Public authorities—Central, State, and local institutions—are committed to initiate and implement a number of programmes having either direct or indirect bearing on improving the nutritional status of different sections of the community. These programmes can range from the choice of research problems designated to develop nutritionally desired strains to nutritional education intended to alter the food preferences and behavioural pattern of households. In between, there are other specific programmes, such as mid-day meals for school children, balwadis or children's homes and other institutional arrangements to provide nutritious food to specific age-groups or classes in the population. The other policy instruments, such as procurement, distribution, prices of food commodities which impinge directly on the nutritional intake of the population have far wider economic implications. Policies cannot be formulated and implemented in isolation of each other without looking into their interaction as well the broader implications for the economy. Apart from the intake of nutrients, the utilisation aspect also deserves attention. This calls for an understanding of factors affecting utilisation of different levels of intake of nutrients. The main objective of our study is to provide an integrated model where the broader but not total implications of various policy instruments can be studied in a realistic and integrated manner. This should help us in analysing the costs to the community of various types of interventions (directly in the nutrition system or indirectly affecting it) with differing intensities so that a suitable mix of policies or interventionist programmes with appropriate magnitudes can be formulated.

Intervention Policies

In order to do this, there is no escape from articulating the objectives of nutritional intervention policies. It is true that these policies so evolved may, on occasions, conflict with other broader objectives of economic development and capital accumulation. However, to go for a more general approach where developmental and nutritional objectives are integrated will require a much bigger research effort. The present limited approach should be viewed on a preliminary move towards that kind of an integrated approach to the problem. The objectives in this limited sphere can be: either attain a certain nutritional level of different sections of the community at a minimum cost or alternatively, postulate the objectives for minimising the nutritional gaps of the vulnerable sections of the community, given the resources that are made available to these programmes. We can choose a mix of these two or other objectives. The basic approach in our opinion, should facilitate our handling these problems with a variety of meaningful objectives which the community could have.

Apart from the constraint of resources, there are certain aspects of nutrition that deserve specific mention. We can conveniently ignore some of them or consider the assumptions that nutrition experts have prescribed – some minimal quantities of nutrients. This may be adequate but it will not be based on a deeper understanding of the role which nutrients play in the growth of the body and mind. There has been considerable research in this area; the role which nutrients play from the stage of conception to a certain age and the growth of various parts of the human body and also the resistance which the body builds up against diseases: the interacting problem of absorption of various nutrients that are fed into the human system. In all these cases, the present studies still seem to be insufficient. We have endeavoured to look at these and relate the demand for nutrients for various classes, particularly for various age groups in the light of biological processes of body absorption and growth. Besides

these, there will be other (behavioural) constraints which will influence both supply and demand. In trying to evolve a model which will give answers to the questions we have posed, we have included "approximations" to some of these physical or technological constraints.

Out Line

In the next chapter, the boiological process of growth is objectively discussed in terms of a conceptual framework for standard man which could lead to specification of nutrition requirements; critical phases of growth have been noted using information from biological researchers; biological absorption of nutrients along with the inter–relationships among the important few are noted; problems involved in accepting unconditionally the WHO/FAO specification of nutrition requirements are also analysed. In chapter 3, we dealt mainly with the physiological behavioural aspect of the demand for nutrients, and examined at some simple specifications of demand functions. It also deals with the supply of nutrients viewed from two sectors: agriculture and non-agriculture: also, some tentative formulations of supply response functions for econometric estimation of agricultural production functions are discussed. The chapter that follows provides a detailed survey taking stock of the existing literature dealing with the specification and estimation of nutrition models with an emphasis on planning for nutrition development viewed from production and consumption viewpoints. Chapter 5 which is the crux of this report, deals with the formulation of integrated nutrition planning models incorporating the decision framework at the levels of consumer; farm; aggregate food consumption; and regional food production.

The model essentially consists of integration of two separate two-stage optimisation models in a multi-period framework: some of the tentative empirical results generated while testing the models are appended to this chapter, using mostly simulated data.

2

Biological Process of Growth

2.1 Framework for Nutritional Factor

What constitutes a normal/standard man physically and mentally is a crucial question in the context of intervention in nutritional systems, particularly when we have to specify the nutritional goals. We shall not be interested in the mental feature at this stage but would like to analyse the factors that need to be taken into account while defining a normal/standard man. These are: (i) different physical characters expected of a person in a given region and climate ; (ii) attainment of potential physical growth given the genetic features of the parents and previous generations; (iii) resistance ability with respect to various infectious diseases and longivity. To our knowledge, no study has come forward with[1] quantitative definition of a normal/standard man on these lines but a less general definition adopted by FAO/WHO and other international agencies to define a "reference man" are available. Here, the weight and height of a pesson in different age groups is defined for a given climatic situation.

After defining a normal/standard man one should examine the nutritional requirements in various stages of life so as to achieve this physical growth. It should, however, be mentioned that the metabolic activities vary from person to

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1. Some attempts to formalise the definition are reportedly made recently, but still the debate seems to be inconclusive both in qualitative and in quantitative terms. "See *PAG Bulletin*, Sept-Dec 1977, 7(3-4), PP. 50-60.

person and hence the same level of intake of food and hence of nutrients need not result in the same type of physical health status even after we make allowances for type of work, climate, sex, etc, as the efficiency of human mechanism in its ability to utilise nutrients makes the difference. Therefore, it looks ambitious at this stage to attempt for a rigorous quantitative definition of standard man. Certain approximations are, therefore, desirable and these are taken up in the subsequent sections.

The mathematical optimisation model given in Chapter 5 of this report incorporates certain simple cases of the problem of attainment of nutritional goals with respect to a standard man. Generalisation of these models to cover the planning for intervention strategies with respect to various biologically defined species of persons and / or age-groups under specified sex, work, and climatic classifications can be carried out. The main problem, however, will remain as one of finding the input–output relation between nutritional intake and physical growth activit es for each of these classifications of human population.

In a dynamic frame as one would expect in case of any system—the initial conditions of the system governing takeoff and or terminal situation, that is, in case of health and nutritional status of human beings the genetic characteristics inherited from the parental genes, and more specifically and crucially on the state of health of a pregnant woman before delivery is very important. The irreversability of certain effects of deficiencies in the health status of the baby in the earliest childhood age prevails to a large extent but there is no denial of the fact that some major effects like that of blindness due to deficiencies of vitamin A are avoidable. Certain other growth characteristics like bone formation under varying nutritional intake possibilities given an initial status or statute of the body of the child are not quantitatively investigated and hence it is difficult to accommcdate in the

mathematical models the exact relationships and hence the difficulty in arriving at a accurate prescription of nutritional intervention strategies. We can take, let us say, N age-groups spreading throughout the span of life of a human being, M physical characteristics and Z number of nutrients affecting the physical system. It is desirable to find out the impact of the varying levels of intake of one or more of these nutrients on one or more of the characteristics in different age-groups. Obviously this is a very complex problem. If this type of information is available (hopefully researchers will concentrate in the next two decades on this), it will be possible to evolve efficient optimal nutrition intervention strategies under varying objectives, and goals. We can easily see that the structure is that of a dynamic multi-period nonlinear optimisation problem.

The discussions that follow deal with the role of the various nutrients during the life cycle, highlighting the consequences of absence of different degrees of the same, the factors contributing to the determination of nutritional requirements, under certain normal conditions the specification of nutritional requirements, etc. Some of these discussions are not necessarily of use in the mathematical models. These will help in evolving policy intervention strategies on a qualitative logical basis given the criticality of lack of certain nutrients in different stages of growth of a person.

Nutritional status at time t of individual i $\left[f^{i}_{j}(t), \right. = \left(f^{i}_{2}(t), f^{i}_{2}(t), \ldots\ldots, f^{i}_{n}(t) \right)$

Also, $f^{i}_{j}(t) = f^{i}_{j}\left(t, \left[f^{i}_{j}(t - \bar{c} \right] c\ (t),\ I\ (t)\right)$, (1)

where c (t) is intake and I (t) a parameter depicting genetic character and/or influence of infection or other diseases when (I) is recursively worked backwards, the impact of parental genes and status of initial health are seen to have

impact for subsequent periods. More generally, (1) can incorporate the inter-dependencies of different $f_j(t)$'s for an individual,

$$f_j^i(t) = f_j^i\left(t,\ f_j^i(t-1),\ f_{k\neq j}^i(t),\ C(t),\ I(t)\right)$$

Since c (t) the nutritional intake vector $(C_1(t), C_2(t) \ldots C_r(t))$ has differential impact on f depending on the choice of combinations of c_1s, we need to have -

$$\frac{\delta f_j}{\delta c_1} \qquad \frac{\delta^2 f_j}{\delta\, dc_m}$$

These expressions are rather difficult to arrive at numerically. If there is a well defined desirable set of nutritional characteristics in each group for persons with specified racial background, sex, occupation, and climatic conditions, the problem of optimal nutritional intervention strategies is soluble by obtaining solutions to the following type of optimisation problem for each specific age-group (assuming the intervention strategies continue for the successive ages).

$$\text{Min } J_i = \left| f_j(t) - \overline{f_j(t)} \right|, \quad j = 1, 2, \ldots\ldots n$$

with respect to set of parameters (controls) C(t), I(t), etc, subject to the behavioural/physiological inter-dependency relations-

i) $f_j(t)$ expressed explicity with reference to the specification (1)

ii) $C_k(t) = C_k\left(I(t), P(t), P^s(t), M(t)\right), k = 1, 2, \ldots\ldots r$

iii) $F_j(o) = f_{jo}, \quad j = 1, 2, \ldots\ldots n$

It may be noted that C_k can be food consumption quantities or nutrients of different types (the index set of k will obviously vary depending on the choice of one or the other type of specification) with the difference that the policy interventions in the first case are in terms of pricing, income and other policies so that the effective consumption meets the requirements of nutritional status.

Since the specifications of requirements according to ideal nutritional status and also empirical establishment of f_i's in (1) are still open problems for nutritionists, we may have to satisfy ourselves at this stage with an approximation: the FAO/WHO revised specifications of nutrient requirements[2] for different age-sex-occupation classifications of populations may be taken as the desired/targetted nutritional objectives (which, in turn, are assumed to lead to some implicit nutritional status) and then appropriate intervention strategies evolved after examining the socio-economic behavioural relations in the consumption activities of different segments of population.

The desirability as well as the limitations of using FAO/WHO's specification of nutrition requirements are discussed at length in section 4 of this chapter. It is worthwhile to mention that the objections raised by Sukhatme[3] on FAO/WHO's specifications may have some relevance when we are taking a dietician's problem of prescribing nutrition and diet requirements on a day-to-day basis. But as we are concerned with long-term approaches for nutritional development, the specification of nutrient requirement should be more or less on annual basis apportioned into daily requirements, and hence the objections need not hold in this case. A detailed discussion on these aspects is given in section 4.

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2. The details of tha basis of FAO/WHO estimates are given in Section 5.

3. Assessment of adequacy of s of diets different income levels. Sukhatme P V. *Economic and Political Weekly*, Annual No. 1978, 13, 1573-84.

2.2 Critical Phases of Growth

Animal growth has been defined by Mitchell[4] to be the summation of those co-ordinated biological and chemical processes that are initiated with the fertilisation of the ovum and terminated with the attainment of body size and conformation of the physiological capabilities, characteristic of the species and of the hereditary background of the individual. In the conceptual cosmos of development, a cell first proliferates, which is growth, then it becomes particular, which is differentiation. The composite is development. Cell proliferation starts at the moment of conception. It increases during pregnancy and gradually declines to a relatively steady state at the time of maturation with cell production and cell loss balancing each other. Different organs have different rates of cell proliferation at different times during development.

The individual inherits a large assortment of genes that determine his basic make-up. Each of the many genes is a definite substance that influences some particular process of the developing embroyo and child. From the time of conception until death, each phase of development is influenced by the interplay of the inherited genes, which are under hormonal control, and the many environmental factors, including nutrition. Healthy growth and development depends upon good nutrition. If malnutrition occurs during the crucial time of nuclear proliferation and continues beyond the age at which this is possible, the development of the body or any vital organ will be affected and the structure can never achieve its full genetic completment of cells, no matter how well it is nourished later. During development, the mammalian organism passes through a number of critical periods, that never return. Failure to make the transition at the right time might be crippling,

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4. Mitchell M H. Comparative Nutrition of Man and Domestic Animals. Vol. 1, Acadamic Press, New York, 1962.

Three critical phases of somatic growth in the life history of humans have been identified : (i) *Final phases of gestation and the exterogestate foetus* (1st 6 months of postnatal life) characterised by very rapid growth in the foetus when growth of vital organs like the brain occurs; (ii) *Period from 6 months to 3 years age*: Here, the transition from breast milk to other liquid and solid foods has to be made and adequacy of supplementary foods is a pre-requisite to healthy development ; and (iii) *Adolescent period :* This has been identified as a critical stage as there is rapid growth during this period, but evidence of effects of poor nutrition on growth and development in this period is less satisfactory.

Malnutrition in a growing child leads to a condition which is a result of multiple disturbances in metabolic pathway and enzymatic activity affecting almost every organ and system leading to functional impairment also. Development and differentiation of tissues are delayed more than growth in size and weight. A stunted physical growth may be accompanied by physiological abnormalities and even retard mental development.

1st Critical Stage—Pre-birth and Infantile Stage :

The first critical stage (the stages on the foetus and the exterogestate foetus) is one where the growing baby is dependent, to a great extent, upon the mother's nutrition. The foetus acquires its requirements from the maternal body through the placenta, while the extero-gestate foetus acquires its nutrients from the mother's milk (bottle-fed babies are exceptions) and from nutrient stores acquired during gestation. Nutrition, not only during pregnancy and lactation but during a woman's whole pre-conceptual life is one of the most important factors affecting her ability to nurture a healthy baby (physically, psychologically and mentally healthy).

The foetus is apparently able to drain out at least a minimum of essential nutrients from the mother, but there is,

however, a limit to such a host parasite relationship and after some time, food shortages would be shared by both mother and foetus. The rate of foetal growth is maximum during the second half of pregnancy and this is accompanied by extensive changes in maternal metabolism and growth of maternal tissues. This results in great stress to the mother and consequently increase her nutritional requirements. The nutritional needs during pregnancy include the normal requirements of the mother, those of the developing foetus, including uterus and placenta and the requirement for building up of reserves in preparation for labour and lactation.

The total energy requirements are increased during pregnancy in order to (1) meet needs of increased basal metabolism (in Indian pregnant women increases of 5 per cent, 5 per cent and 12 per cent in B. M. R. in the 1st, 2nd, and 3rd timester, respectively, have been reported) ICMR (1968,[5] (2) provide energy for growth of the foetus and other maternal tissues; (3) provide for increased cost of energy for the movement and body activities of a heavier mother.

The amount of protein needed during pregnancy is greatly increased, particularly in the second half of pregnancy, when the rate of protein acquisition by the foetus is the highest. The growth of maternal tissue also require additional dietary protein. The maternal body shows a great capacity for nitrogen retention which may be compensatory for later loss of nitrogen during parturition and lactation. The need for minerals, especially that of calcium, iron and iodine, is increased during pregnancy. The greatest need for calcium is in the last pre-natal month, when maximum calcium is deposited, in the foetus, as most of the calcification of bones occurs in the last two months of pre-natal life. Calcium is

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5. ICMR. Dietary allowances for Indians. Gopalan C, Narsinga Rao B S. *ICMR Special Report*. 1968, Serial No. 60.

retained by the maternal body beyond the needs estimated for the foetal and new maternal tissues and serves as useful stores for successful lactation. The quantitative need for iron increases with the progress of pregnancy due to rapid expansion of red cell mass and blood volume for foetal and placental needs, for stores in foetus (in liver) and as a safeguard against losses during parturition. This need is in addition to the basal physiological losses in a woman although cessation of menstruation during pregnancy represents a saving of iron. Need for iodine susceptibility to goitre is increased in pregnancy, due to increased thyroid activity and increased basal metabolism.

There is thus a need for increased amount of several of the vitamins during pregnancy. Foetal liver stores of vitamin A are dependent upon adequate amounts in the maternal diet. Need for vitamin D to ensure efficient utilisation of calcium and phosphorus is increased and when not met leads to softening of bones, as calcium and phosphorus are withdrawn directly from the mother's bones. Decrease in blood levels of ascorbic acid as pregnancy progresses indicate a need for this vitamin. The increased intake of calories and protein result in a proportionate increased need for B-complex vitamins, especially thiamine, riboflavin and niacin. The increased need for niacin is reflected in the fact that the conversion of trytophan to niacin is more efficient during pregnancy. Additional folic acid and vitamin B_{12}, to provide for rapid increases in blood volume, red cell mass and for foetal storage must also be provided in the diet.

Thus, the stress of pregnancy results in an increased demand of almost all nutrients over the normal requirements. Maternal malnutrition, whether general or specific, leads to foetal malnutrition which may result in serious curtailment of an infant's potential for physical and mental development.

2nd Critical Stage (pre-school age) :

The second critical stage is the transitional stage (period from 6–9 months to 3 years) when the transition from a milk diet to other foods must be made. The term "pre-school" covers the above stage continued till 5 years of age.

The volume of breast milk secreted reaches a peak around six months and diminishes after that time, while the nutrient needs of the baby increases. The growth till about 2 years proceeds at a faster rate, then slows down and continues at a slower rate throughout the childhood. The need for calories and protein increase for the bigger baby, but the requirement per unit body weight becomes increasingly lower after six months. The need for calcium, phosphorous and vitamin D increases to provide for rapid skeletal development. As the stores of iron, vitamins A and C acquired during gestation are being exhausted, the dietary needs for these nutrients also increase considerably. Other vitamins and minerals must also be provided in the diet for helping the growth process and for body metabolic processes. Around the sixth month of life, therefore, supplementary feeding has to be resorted to, to maintain the expected rate of growth in the child. Weaning is an important period in the life of an infant and begin from the moment a supplementary food is started till the child is taken completely off the breast (or bottle in the case of artificially fed infants) since, the infant is switched over from milk diet which is insufficient to meet its needs, to other foods, weaning assumes considerable significance from nutritional point of view. Care must be taken in selection and introduction of supplements (liquid, semi-solid, then solid) which will meet the nutrient requirements of the child and will gradually wean it away from a milk diet to one which will provide the required nutrients in adequate amounts. The foods given to the baby at this time will determine the pattern of its growth, its susceptibility to illness and its developing

into a physically and mentally healthy adult. Nutrition deficiency in adults has been discussed in Appendix A.

Nutritional Problems in Transitional Stage

This transitional phase is the most vulnerable with regard to onset of malnutrition. The second semester of the infancy is characterised by inadequate supplements of largely carbohydrate gruels and pastes (in the low socio-economic groups in developing countries) and early signs of undernutrition and malnutrition, infections, and diarrhoea set in, though full-fledged kwashiorkor and marasmas are generally seen only beyond the first year.

Protein-calorie malnutrition is the major nutritional problem among the children from ages 1-5 (pre-school age group) and results mainly as a result of inadequate supplementary feeding. Growth retardation is one of the earliest signs of PCM and is reflected in substandard body weights. Growth weight is qualitatively expressed by expressing the body weight as a percentage of the expected body weight for a particular age. By this criterion, it has been reported by Rao et al[6] that 80 per cent of children belonging to poor income group in India suffer from either grade II malnutrition[7] or grade III malnutrition. Under-nutrition not only leads to PCM but is also an important factor in precipitating other conditions resulting from deficiency of specific nutrients.

Nutritional anaemia, due to insufficient iron and folic acid and vitamin B_{12} in the diet is one of the major nutritional problems in this age group. Surveys carried out by

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6. Rao N P, Singh D, Swaminathan M C, Indian Journal of Medical Research 1969, 57, 2132.
7. Gomez scale of classification of malnutrition.

Degree of malnutrtion	deviation below reference
I (mind)	10-25 per cent
II (moderate)	25-40 per cent
III (severe)	over 40 per cent

ICMR[8] show that 52 per cent of the toddlers among the poor socio-economic groups are anaemic. Orolingual manifestations of vitamin B complex deficiency like angular stomatites, raw and red tongue, etc, are frequently seen among toddlers. Signs of healed rickets, especially knock-knees and bow-legs and some signs of active rickets like beading of ribs are also reportedly common in pre-school and school-going children.

The peak incidence of vitamin A deficiency is in the age group 1-5 and is primarily due to low amount of vitamin A or its precursors in the supplementary foods given. This deficiency is one of the main causes of blindness in India. In school age children, adolescence and pregnant women, signs of this deficiency are seen but rarely lead to complete blindness. Conjuctival and corneal xerosis and bittots spots are seen to the extent of about 10 per cent in pre-school children in India (ICMR) and about 5-10 per cent in school children, the incidence being concentrated in the lower socio-economic groups. Clinically manifest deficiency diseases do not reflect the whole picture of improper supplementary feeding or of poverty and inadequate intakes. More important from the social point of view is sub-clinical malnutrition since it is more extensive in its incidence and insidious in its effects. While it increases susceptibility to infection and other diseases, it also affects physical development, health and efficiency and reduced longevity.

3rd Critical Stage—Adolesent Stage:

The adolescent years form the second period of very rapid growth .The growth spurt begins in girls around 11-13 years and in boys around 13-15 years. The rate then tapers off to the relatively small gains characteristic of early adulthood as final body size is approached. The skeleton reaches

8. ICMR. Dietary allowances for Indians. Gopalan C, Narsinga Rao B S *ICMR Special Report*. Ser. No. 60, 1968.

its full size at 17 years in girls and at 20 years in boys. The basal metabolic rate is also accelerated. These years are also about the most active period in life. The rapid biological and psychological changes taking place make the adolescent vulnerable to physical and psycho-social environmental influences. The significance of good nutrition and health in pre-adult period for future parenthood and the next generation must be recognised.

Energy and protein requirements for basal metabolic activity, physical activity and for growth are considerably increased. Adequate intakes of calcium, phosphorous and vitamin D are needed for rapid skeletal development. Girls who are subjected to the deficiency of these nutrients may develop a small pelvis, causing difficult labour during pregnancy in later life. The iron requirement increases to meet the demands of growth, muscle mass formation, blood formation, etc. The onset of menstruation in girls increases iron requirement considerably. Due to the high thyroid activity during adolescence, requirement for iodine is also increased considerably. The requirement for other vitamins are also correspondingly increased.

Undernourished children throughout childhood and adolescence will maintain a slower rate of growth than normal nourished children, but the growth continues for a longer time, although a substantial height deficit remains in these groups when growth eventually ceases. Maximum divergence in height occurs during the period of the adolescent spurt. Sexual development is correlated with nutrition, for example, the average age of menarche in malnourished girls is higher than in well nourished ones. In India, the adolescent stress period in girls is often combined with the stress of pregnancy due to early marriages, so that nutrient requirements are elevated extremely and a number of nutritional problems arise

The summary table 2.1 indicates the importance of various specific nutrients at different stages of growth with respect to main characteristics: bones, brain and central nervous system, other body tissues and specialised tissues. Such an identification of crucial requirements of different nutrients is useful while attempting any priority/supplementary feeding programmes or in governmental intervention to avert nutrition crisis. This information is also useful for disaggregated age-group specific integrated nutrition models to evolve optimal intervention programmes. In the table, the priority nutrients are indicated. Other nutrients are also necessary but they assume relatively less crucial role.

Summary Table 2.1 : Various Speceific Nutrients

Phase I : (up to 6 months)

1.	Bones	: Calcium, Phosphorus, Vit. D
2.	Brain and central nervous system	: Protein and B-complex
3.	Other body tissues and specialised tissues	: Calories, protein, iodine, B-complex, Vit-C, Vit. A and Iron.

Phase II : (6 months to 3 years)

1.	Bones	: Calcium, Vitamin A, Phsophorous, Vitamin D.
2.	Brain and central nervous system	: B-complex, Protein
3.	Other body tissues and specialised tissues.	: Calories, portein, iodine, B-complex, Vit.C, Vit. A and Iron

Phase III : (13 years to 18 years)

1.	Bones	: Calcium, Vitamin D
2.	Other body tissues & specialised tissues	: Calorie, protein, iron, iodine, Vit. B and Vit. C

2.3 Biological Utilisation of Nutrients, Nutrient Inter-Relationships and Vitamins

The utilisation of a nutrient by the body is dependent upon various factors :

(a) the potency of the form of nutrient in the food eaten

(b) the processes, including cooking, it is subjected to, which effects its availability

(c) the presence of other nutrients in the food items or diet which may have favourable or adverse effects

(d) the digestive and absorptive process which are influenced by the physiological and pathological state of the body

In the average diet about 97-98 per cent of carbohydrates is completely digested and absorbed. The fuel factor of 4 calories per gram is based on this degree of digestibility. Carbohydrate metabolism is dependent on the level of the vitamin thiamine. The requirement for thiamine in the diet therefore increases as the proportion of carbohydrate in the diet increases.

Normally 93-98 per cent of the commonly used fats are digested, and absorbed. The utilisation of fats in the body depends upon the availability of lipotropic factors, which include the amino acid methionine, also vitamins of B-complex group—choline and inositol.

Proteins : The utilisation of the protein in the diet for growth or energy processes in the body is dependent upon a number of factors :

(a) Protein quality of food. the amino acid composition of the food influences the quality. Amino acid imbalances also influence the quality.

(b) The energy content of the diet.

(c) The presence of other nutrients in the food in combination with protein which affect the availability of amino acids.

(d) Combination of foods present in the diet which result in a better biologically complete protein depending upon the resultant amino acid composition.

(e) Presence of other nutrients, toxic factors in the diet which may interfere with the digestion of the protein.

(f) Presence of cooking which may result in changes in protein structure, affecting amino acid availability or which may cause undesirable chemical combinations which lower protein quality.

Protein quality measures the efficiency with which a single protein is used for growth or maintenance and is an attribute of the protein per se, depending mainly on its amino acid pattern, while the efficiency of the utilisation depends on both the quality and quantity of protein in the diet and the adequacy of the total diet, as well as on environmental conditions and the age and physiological state of the recipient. The quality of protein has been expressed in several ways(see Appendix B).

Protein Energy Inter-relationships

When energy intake is inadequate to meet the body requirements for basal metabolism, physical activity. etc, the protein in the food is diverted to meet energy needs—energy needs have priority of being met before protein needs.

This priority of need for energy over protein synthesis is because synthesis is itself an energy requiring process. Protien

utilisation in an adult individual on an adequate protein intake, and in nitrogen equilibrium will respond to changes in the energy content of the diet. If energy value is lowered, there is increased nitrogen excretion showing that protein is being used for energy. In contrast, if calorie intake is increased nitrogen retention also increases, indicating that protein previously diverted for energy is being used for protein synthesis. The energy level of the diet has been shown to be the critical factor in periods of protein acquisition, during growth, relation, pregnancy, etc. The effects on protein utilisation of: (1) increasing calorie intake with protein remaining constant (Fig B) are illustrated graphically.

As calorie intake increases with constant protein, protein utilisation as measured by carcass analysis increases to a maximum, beyond which no additional protein utilisation occurs. As protein intake increases with calorie intake constant, protein utilisation rises sharply to a peak rate and then the rise becomes progressively less. Fig, C (based on the extensive data of short-term experiments on nitrogen balance in adults) illustrates the fact that at any given level of protein intake, the nitrogen balance is sensitive to energy intake. It is seen that as the energy intake is increased, the protein loss is decreased but only up to a point. Thus, on a no-protein diet, calories spare no protein to start with but it is not until the energy intake exceeds 2,200 calories that the loss is stabilised to about 40g of dietary protein. In other words, a man must be provided with 40g of dietary protein to meet his body need assuming that energy intake is not limiting. On an intake of 40g of protein, a zero loss of nitrogen is not found and it is seen that a man will need to take more than 2,200 calories in order that he may retain and synthesise the 40g of proteins

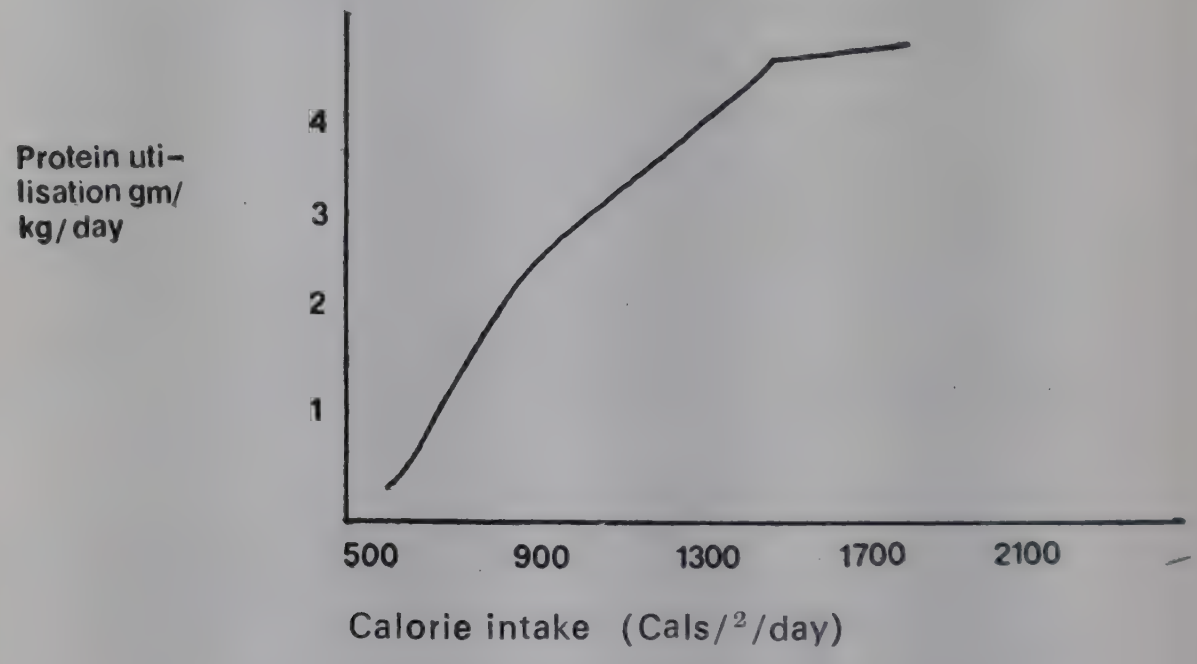
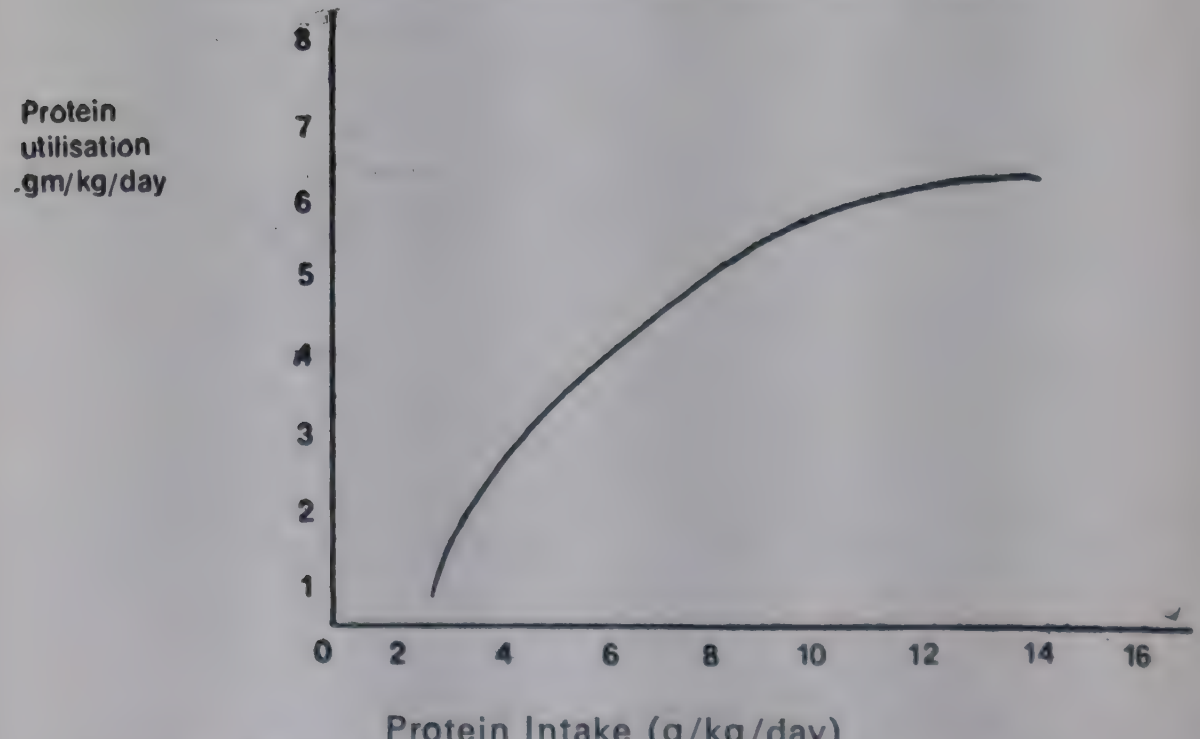


Fig. B : Infuence of level of protein intake on protein utilisation
Constant Calorie Intake (Av. 1630 Cals/²/day)



Source : Benditt E P. *et. al. Journal of Lab. Clinical Med.1958, 33, 257.*

that he actually does eat in order to meet his daily needs. It is seen that when the energy intake is adequate and above 1.5 times the calories needed for basal metabolism (BMR) then the protein is used fully and meets the body needs. If, however, the food intake is restricted to meet only the needs for basal metabolism then the efficiency of protein utilisation is zero. The energy needed to maintain nitrogen balance is, therefore, 1.5 x B. M. R. energy. If the energy intake is excessive, it has been seen, that man can maintain nitrogen balance on incredibly low protein intakes. Fig. C shows that the excess protein over and above body needs does not benefit protein balance. When the intake of dietary protein is higher than the body needs, the excess protein is diverted to the provision of energy.

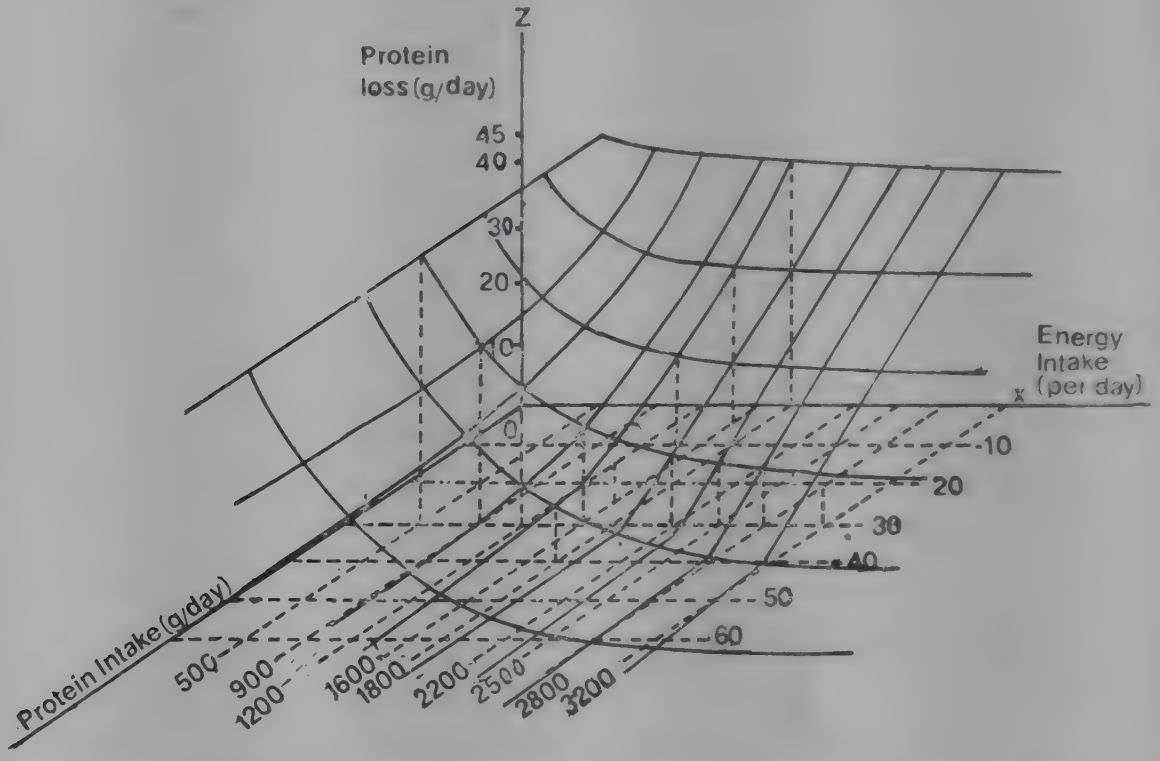
Protein Calorie Ratio

The protein-energy ratio in a given diet is calculated as follows : amount of dietary protein in grams, times the specific energy value per gram of that protein, divided by the energy content of the total diet. The energy value of 4k cal per gram is used for protein and the final ratio is expressed as per cent.

$$\text{Protein calorie ratio} = \frac{\text{g protein in diet} \times 4 \times 100}{\text{Total calories in diet}}$$

Other factors affecting the protein utilisation are: (1) the contribution of fat and carbohydrate to the total calories in diet–when a greater proportion of calories are from fat, there is bound to be a negative nitrogen balance, because fat is not preferred for oxidation to the extent of carbohydrate and hence some protein is diverted for energy purposes; (2) the time lag between the intake of proteins and calories within a day. The proportion of proteins and calories at a particular meal will affect the utilisation and an intake of protein which meets the daily requirement but which is concentrated at one meal,

Fig C : Estimated Protein Loss (g/day) by an Adult taking a Diet Restricted in Protein or Energy, or Both,



Ref : P.V. Sukhatme, The Protein Problems, its size and nature. *JRSS Ser A (Gen) 1974 137 IIr p 177*

will not ensure it being utilised for synthetic purposes, unless it is accompained by the desired proportion of calories. The desirable protein–calorie ratio should be maintained at every meal for good protein utilisation, and not the ratio in the total daily intake.

Vitamin A

The absorption of vitamin A as retinol or β carotene in the small intestine is influenced by several factors. Dietary fat enhances the absorption, as both β carotene and retinol are fat soluble. The requirement of vitamin A, in a diet containing adequate fat is lowered as efficient absorption is ensured. Bile is essential for the absorption of carotene. Anti-oxidants like vitamin E and ascorbic acid enhance the utilisation of the vitamin, by preventing its oxidation and hence the lower requirement. Mineral oil may interfere with the absorption, particularly if taken simultaneously with food. High temparatures oxidise the vitamin and about 70 per cent reported to be lost during frying of foods.

The quantity and quality of protein also affects the requirement Increased intakes of protein during growth period causes an increase in the growth processes which result in an increased requirement of vitamin A for the body. In protein-deficient states like Kwashiorkor, associated vitamin A deficiency sets in due to impaired transport and mobilisation of vitamin A which results in an increased dietary requirement of the vitamin.

Vitamin C (Ascorbic Acid)

The portion of dietary vitamin C that will be utilised by the body depends upon the previous diet and tissue saturation level. High temperatures, exposure to air, solubility in water, heat, alkali and dehydration are detrimental to the retention of ascorbic acid in foods In vitamin C deficiency, associated anaemia occurs due to impaired ability of body (i) to utilise

stored iron, (ii) to absorb iron, and (iii) to impaired folic acid metabolism. Megaloblastic anaemia of infancy is due to combined deficiency of folic acid and vitamin C. Vitamin C is also necessary for the oxidation of the amino acid phenylalamine to tryoxine and in its deficiency, tyrosine synthesis is impaired and a dietary requirement for this amino acid may arise.

Vitamin D

Vitamin D is fat soluble and hence the fat content of the diet influences its absorption. Vitamin D has a favourable effect on both calcium and phosphorous absorption from the intestine. It effects greater phosphorus utilisation for bone mineralisation. It appears to code for a hormone which synthesises the protein needed for the mobilisation of calcium from the intestine. The three nutrients are inter-related in a complex manner.

Vitamin E

The requirement of vitamin E increases when the rancidity of the fat in the diet is high, because rancid fat causes oxidative destruction of vitamin E. Selenium appears to exert some vitamin E activity and lowers the requirement for vitamin E, when present in adequate amounts in the diet.

Thiamine

Losses of thiamine during stroage, processing and cooking are considerable and occur as a result of (1) the solubility of this vitamin in water, (2) the ready destruction in the presence of alkali, (3) high temperatures, and (4) the prolonged exposure to heat. The proportion of fat, carbohydrate and protein contributing to the total calorific value of the food influences the requirement of thiamine. The requirement is increased when the proportion of carbohydrate is

higher as carbohydrate metabolism is dependent upon its coenzyme activity. Fat and protein exert a thiamine sparing effect, as also alcohol. Low dietary calcium and phosphorus ratio has been found to enhance thiamine synthesis by the intestinal bacterial flora and reduce the dietary requirement of thiamine. This does not, however, imply the desirability of reduced intake of calories.

Riboflavin

The absorption of riboflavin poses no problem but the vitamin's sensitivity to light causes considerable loss of potency, and the use of alkali results in the destruction of the vitamin and reduces its availability. The requirement of riboflavin is related to the energy content of the diet and the proportion of fat, carbohydrate, and protein. Excess carbohydrate reduces riboflavin requirement, whereas excess fat increases the requirement, due to the greater role of flavoproteins in fat metabolism. A low protein diet causes increased urinary excretion of the vitamin and decreased tissue storage, because the decreased availability of protein for flavoprotein formation. Associated riboflavin deficiency with protein deficiency is commonly seen. The quality of carbohydrate affects the synthesis of riboflavin and other B-complex vitamins by intestinal flora.

Flavoprotein coenzymes are needed for pyridoxine phosphate oxidation in the body and hence in a deficiency of riboflavin, there is conditioned pyridoxine deficiency. Thiamine deficiency can cause impaired absorption of riboflavin and thereby increase dietary requirement of riboflavin.

Niacin

This is readily absorbed from the small intestine and there are no serious losses in cooking. Tryptophan, an essential amino acid is a precursor of this vitamin and a diet

containing liberal amounts of good quality protein with considerable tryptophan will provide enough niacin to meet the requirement, even though the diet is low in preformed niacin (60 mg tryptophan = 1 mg niacin). When the quality of protein is poor, and the tryptophan content is low, tryptophan is used preferentially for protein synthesis and not for conversion to niacin.

High leucine content in the protein (eg. in jowar) interferes with tryptophan metabolism and decreases its conversion to niacin. Similarly an imbalance of amino acids, isoleucine and leucine which complete for absorption sites in the intestine, affect the metabolism of tryptophan and thereby niacin nutrition status. The vitamin pyridoxine (B_6) is involved in the conversion of tryptophan to niacin, and a deficiency causes the impaired conversion and increases the requirement for pre-formed niacin in the diet.

Minerals : Calcium

Even if adequate amounts of calcium are present in the diet, a deficiency may occur because of the various factors which affect its absorption in the fat. The ratio of calcium to phosphorous in the diet has an important bearing on the degree of absorption, and with a marked excess of either in the diet, the faecal excreation of both increase. There may be a marked loss of food calcium due to an impaired fat absorption. The fatty acids which result out of fat digestion, if not absorbed, will combine with calcium to form insoluble calcium salts which are excreted in the faeces. Oxalate in certain foods (green leafy vegetables) and phytic acid (cereals) cause negative calcium balance because of the formation of insoluble salts of calcium which cannot be absorbed. Calcium absorption has been seen to increase with the increased protein consumption. When the diet is deficient in certain essential amino acids, such as lysine, the utilisation of calcium is poor. Vitamin D has the greatest influence on

calcium absorption and utilisation. It increases the efficiency of absorption even under conditions in which the intestinal calcium is poorly soluble. Calcium is absorbed against a concentration gradient requiring energy which is stimulated by vitamin D. The need for calcium may be a potent factor in absorption, that is, the mechanism of absorption is sensitive to the requirements of the organism. Because of the various factors affecting calcium utilisation, it will be difficult to judge if an intake of calcium will be sufficient to meet the individual's requirements, unless associated factors in the diet are taken into consideration. For instance, calcium from milk sources will be better utilised than from green leafy but if taken with cereals containing a considerable amount of phytic acid, may be rendered insoluble and the utilisation will be lowered.

Iron

The extent to which reduction of iron from ferric to ferrous form occurs in the intestine affects the utilisation of dietary iron. Ascorbic acid brings about this reduction. The absorption of iron is increased when iron stores are low and therefore efficiency of utilisation of iron increases in iron-deficient patients. Cereals contain phytate and phosphate which interfere with iron absorption and absorption values of 10 per cent or less have been reported in Indian dietaries. However, as calcium also combines with phytic acid in food stuffs, an increased intake of calcium spares the iron and increase its absorption. Ascorbic acid intakes in high levels also counteract the effect produced by phytates in the diet. The presence of animal protein in the diet has a favourable effect on iron absorption. The total availability of iron is higher when the diet contains meat products than in its absence.

As is seen above, the utilisation of a nutrient, completely by the body is not ensured by just supplying it in the required amounts in the diet. The close dietary and metabolic inter-relationships between nutrients must be taken into con-

sideration while setting up recommendations for nutrients in diets and also in the actual planning of balanced diets.

2.4. Specification of Nutrition Requirements : Critical Assessment

Interest in the specification of nutrition requirements for different physiological classes of population arises mainly from one or both of the objectives : (i) identifying and estimating the population that is nutritionally at risk, and hence poverty [9](Dandekar and Rath) (ii) evolving specific policies to direct and indirect intervention for reducing specific types of nutrient deficiencies. For policy purposes, an approach for the estimation of population at risk in terms of nutrition should be based on a design evolving composite indicator of nutritional health status or health status (expressed in terms of nutritional status and other functional features) which can distinguish features like age, sex, environment, activity levels, and historical physiological background. After agreeing on such an index, it becomes relatively easy and meaningful to evolve sampling techniques (may be extended versions of multi-stage stratified random sampling designs) for estimation purposes. However, with the existing state of knowledge, the goal seems to be rather elusive.

Nutrition Requirements : Issues

The specification of minimum nutrition requirements for any population of human beings, given the age, sex, and other relevant characteristics (like weight, height, pathological and physiological status), remains a complex issue despite the knowledge of several investigations in this regard. This problem is faced with several difficulties of designing a meaningful sampling experiment for collecting relevant data and interprinting them for different segments of population and also policy purposes. Added to these when a certain features of

9. Dandekar VM, Rath N. Povery in India. *Economic and Political Weekly* 1971, 6 (1, 2).

the physical environment, for instance, in respect of quality of water and air are to be assumed as fixed or as being not amenable to improvement in a given region (in a horizon like a decade), the prescription of minimum nutrition requirements has to make allowance for possible underutilisation due to these factors. This leads us to the main issue: how to specify the nutrition requirements for different categories of individuals characterised by age, sex, activity, and for a given category for different physical environments and or under different categories of historical (i. e. at birth and subsequently) nutritional status of individuals?

Further, there is an ethical question : if the observed anthropometric or other features at an early stage of life of a person reveal that he is under-nourished (in some sense), do we expect the person to perform "normal" function in later stages of life, and if so, how to prescribe the nutrition requirements? Normally, using the observed characteristics of a person, there are two ways of attempting the determination of nutritrition requirements : (i) the nutrition needs as dictated by physiological features, (ii) as in (i) and an additional requirement ($\pm$) to improve the nutritional status in order to achieve the desired levels (and perform normal functions in subsequent periods). This is related to the issue: What is the probability that a malnourished person as detected in early stages or life catches up to "normal" growth, under varying levels of intake of nutrients? How about mental performance under such conditions? Unambiguous answers to these prolems are hard to find in nutrition science as of today. However, one argument that develops forcefully is that the specification of nutrition requirements in the non-adult age-groups is to be closely linked with, not only the current period physiological parameters but also the initial conditions or features prevalent in the previous periods and the terminal specification of the required status features. When the problem is represented by a formal mathematical optimisation model, it is

clearly noticeable that the optimal quantities of nutrition requirement are sensitive, *inter alia*, to initial conditions, terminal specification, transformation function governing the process conversion of nutrient inputs into physiological output.

The minimum physiological requirement of a nutrient has been traditionally defined as the least amount of nutrient that will prevent symptoms of clinical signs of nutrient deficiencies, maintain bio-chemical levels in tissues and tissue fluids commensurate with a normal health state of the body and mind and maintain normal physiological function. To quote Olcott : Primarily we need proteins fats, carbohydrates, and, in smaller amounts, vitamins and minerals. But these categories can be broken down to fifty or sixty separate items necessary for optimal nutrition. We do not know that 'optimal' means for man. Goal choices are: fast growth, athelectic ability, resistance to disease and toxins, mental health, and logevity, all reasonable goals; but we simply do not know if they require the same relative nutrient intakes".[10] There are mainly two difficulties in the measurement of requirement of the nutrients: (1) the variety of criteria (as stated above) that have to be taken into account when recommending a suitable number or range of given nutrients —the problem of lumping of a vector of parameters into a scalar measure; (2) the intra-individual and inter-individual variations in the requirement of nutrients for a given physiological population group. Apart from these, the other factors which bring in distortions in the accuracy of determination of nutrition requirements are :

(a) All symptoms and consequences (using clinical/anthropometric or bio-chemical methods) of deficient of one or more nutrients are not fully known in medical

10. Olcott H S. What is known about human nutritional needs? *American Journal of Agricultural Economics* **1976, 60 (5) pp. 800-802.**

science; the several metabolic functions of a nutrient make it difficult to decide which function should be tested and whether the most appropriate index of the impact of the nutrient.

(b) Individuals adapt over time to reduced intakes when the reduction is in a certain range and the impact of the reduction may be difficult to measure and is also the function of the length of the period over which the reduction occurs.

(c) Metabolic inter-relationships exist between nutrients to the effect that the requirement of one depends upon the level of intake of another. The functional inter-relationships are not clearly known.

(d) The body has a capacity to store some nutrients, particularly vitamins, which are subject to seasonal fluctuations in supply. A slight deficiency of a nutrient might go unnoticed due to a state of compensation by the body when reserves are diminished. It is difficult to specify accurately the level of nutrient intakes that will maintain body stores at optimal levels.

Given these salient features that need to be taken into account wherever meaningfully accurate estimates of minimal nutrition requirements of an individual or class of individuals with given description of characteristics are to be prescribed, the problem remains a complex one, and more so, when certain important aspects (like physical environment including sanitation, infectious diseases, etc.) affecting the utilisation of nutrients are to be treated as fixed and given parameters. These environmental factors are also very important whenever they are not expected to undergo changes in the period for which the prescribed nutrional requirements are taken as targets for interventionist schemes affecting the nutrient supply and intake in the community. Since the

ultimate objective of such intervention schemes in the context of public policy is to achieve certain desired nutritional (and more generally, health) status of the community, we cannot confine ourselves to the prescription of nutrient requirements assuming perfections of the environment (of complete absorption of nutrient intake). Also, we need to examine whether and to what extent the intraindividual and inter-individual variations in nutrition requirements as noticed on a daily or weekly basis are relevant for planning nutrition intervention over periods like a few years.

Current Debate

Much of the trouble in respect of nutrition requirements as proposed by FAO/WHO[11] lies partly in the misguided interpretation of the same. The uses recommended by FAO/WHO are : (i) recommended intakes are intended for the use of planners in order to estimate the food requirements on an aggregate for a region or nation for a period like a year; (ii) they can be compared with the actual consumption figures determined by foood consumption surveys and serve as guide for drawing up rational scales.

The greatest pitfall lies in the use of the recommended intakes for comparison with consumptions figures and then making judgment on the nutritional status of the individual. Measured intakes of nutrients can only be compared with physiological requirement levels to give estimates of probability of deficiency. Since the intake of nutrients as well as the physiological requirement of nutrients follow certain

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11. FAO/WHO. Energy and protein requirements. *Report of Joint FAO/WHO Ad hoc expert committee*. Technical Report Series No. 522, 1973.

different probability distributions, the design of an observation experiment on the intake of nutrients for an individual with given characteristics need not hold good for a group of individuals with heterogeneous characteristics even if they belong to the same age-sex occupation group However, in order to get an understanding of the process and to estimate under nourishment, it is worthwhile to examine the properties of an approximate probability distribution which might govern an individual's nutrition requirements over different time periods and of a reasonably homogeneous group of individuals in a period of time.

It is well-known that there exist variations, both in terms of intake of nutrient units and of requirements of the same- across different individuals and also across different time points in a time-horizon (may be a day, a week or a year for a given individual. Now the question is whether the variations are significant to warrant an adjustment in the "mean" requirements, in order to arrive at "safe" levels of nutritional intake. To a large extent, the answer depends on (1) the heterogeneity groups of population under consideration, for the purpose of inter-individual variation, and (ii) the magnitude of time-span under consideration, for the purpose of intra-individual variations.

The estimated variance σ_1 in the requirement of a man is energy equilibrium maintaining body weight will depend on the frequency of observations concerning the physiological features and intake of nutrients. It is likely to be constant across years but non-constant for small periods. It is easy to see that the variance of an estimate of mean requirement is inversely proportional to the number of consecutive observations in comparable time periods and, therefore, reduces to a small constant when the number of time periods is large, The variance σ_2 in the nutrient requirements across individuals, if we take a large section of population is likely to be constant.

According to Sukhatme[12] "when the observed intake for any day or period of less than the average requirement, worked out from the FAO/WHO scale, it cannot be taken to imply that a man is undernourished, ... unless his intake is so low as to be below the lower limit of the confidence interval for the chosen level of significance. It follows that the proportion of individuals below the lower critical limit (μ-20$\bar{\sigma}$)[13] may be taken to represent, the estimate of the incidence of under-nutrition". He, therefore, feels that the average energy need of an individual should not be taken as the minimum need, "ignoring the fact that energy needs vary between and within individuals even of the same age-sex group." It is apparently not logical to ignore the specific period under consideration for which the observed intake is lower than the critical limit for the purpose of assessing the impact of such intake on nutritional status For example, if the period is long enough, say, one year, the inference drawn by Sukhatme based on weekly or daily observations may be misleading. Even in case such inference for a suitable period were valid, we cannot take μ–2$\bar{\sigma}$ as the benchmark for defining undernourishment since intra-individual variations and inter-individual variations in requirements will fluctuate around this new critical limit and leads to undernourishment for those whose average requirements are greater than or equal to. The deduction of 2$\bar{\sigma}$ from μ is rather arbitrary. An experiment which computes $\bar{\sigma}$ on the basis ex-ante information need not have its validity ex-post in the human biological system as the system undergoes change in this process.

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12. Sukhatme P V. Assessment of adequacy of diets at different income levels. *Economic and Political weekly 1978*, (Special No. 13), pp 1373-84.

13. Is the average nutrition requirement for the FAO WHO "reference" man and the standard error of the estimate.

According to Sukhatme and Margen[14] "the principle of evaluating intake data laid down by the FAO/WHO expert committee, namely, that an individual eating below the safe level," does not apply in the case of our model, except, of course, at the extremes of low intake, at levels where homeostasis breaks down. While recognising the break-down possibility due to variations in the quantum of intake during a short period like a day or a week, the authors do not seem to have recognised a similar possibility resulting from lesser variation or reduction in intake but persistent over longer period, in other words, a state of the physical system (given its main non-flexible characteristics in terms of genetic inheritance, age, environment etc.) can be attained in several combinations of the sequences $\left[X_t \right]_{t=1}$ of intake levels in successive time periods t=1, 2.....(1 being current period), other factors remaining the same. This leads us to infer that homeostasis breakdown state can well occur due to several possible sequences of intake, even if each element of the sequence falls within tolerable limits of variation prescribed for short periods. Thus, any prescription of nutrition requirements as the basis of the so called critical lower limit established on the basis of a first-order auto-regressive process description of daily requirements can lead to malnourishment. Further, in the absence of clear norms or basis of designing a sampling experiment to estimate it could be at best a rough (and flexible) estimate.

In the light of the arguments, it appears that Sukhatme's claim is relevant only in assesing tolerable limit of nutrient requirements for an individual for a short period like one day or a few days and is not valid for a persistent period of time like one year and at an aggregate level for the population. Thus, it may be closer to a dietisian's problem than to a

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14. Sukhatme P V, Margen S, Models for protein deficiencies. *American Journal of Clinical Nutrition, 1978*, 31, pp. 1237-56.

policy—maker's problem. Since the nutrient requirements are normally estimated considering the nature of nutrients of active healthy individuals in a given age-sex occupation group, it should be possible to spread these observations over sufficiently long periods like one year so as to accommodate both inter and intra-individual variations. The following well-known result may be useful to design a sampling experiment in order to estimate the mean nutrition requirements for a given age-sex-occupation group on an annual basis :

If the sequences X_{1k} .....X_{rk} of random variables where r is a definite number and k = 1, 2 ....., converge stochastically to fixed values a_j ————, a_r then an arbitrary rational function R (X_{1k} .....X_{rk}) converges stochastically to the fixed value R (a_1 .....a_r) if this value is finite. One can possibly define R (.....) as the mean value function with a proper choice of index r.

Estimation of Manitude of Poverty

The limitations of Dandekar and Rath (1971) approach for the estimation of poverty (in India) have been pointed out by Sukhatme.[15] The drawbacks of Sukhatme's alternative approach have been discussed above. In an interesting recent investigation, Bliss and Stern[16] have explained the sensitivity of the estimates of magnitude of poverty with respect to the specification of nutrition (mainly calories) requirements and expressed serious doubts about the reliability as well as the desirability of estimating magnitude of poverty on the basis of specified nutrition requirements which are of dubious validity. They raised several pertinent questions like: what are the consequences for an individual in terms of ability to perform tasks of being a certain weight? What is the minimum weight (if it exists) an individual would require to

15. Sukhatme P V. Incidence of undernutrition. *Indian Journal of Agricultural Economics* 1977, 32(3), pp. 1-7.

16. Bliss C, Stern N. Productivity, wages and nutrition (Parts I to II). *Journal of Development Economics* 1978, 5, pp. 331-98.

be to perform a given number of tasks and how does this weight vary with the number of tasks? These issues were raised in the context of examining the relationship between wages, productivity, and nutrition and were addressed for the age-group that is relevant for the description of working population. More generally, when we are concerned with every age-group in particular with the vulnerable age-group (mainly 0–5 years), issues are obviously more complex.

The debate contained in the earlier sections highlighting the need to recognise the initial physiological conditions and desired targets in respect of these and related features at a later date (which include productivity, longevity etc.) becomes then relevant. Even for the working population, weight being only of the many anthropometric measures, it is natural to seek the desirable levels of physiological/anthropometric specifications and their inter-relationships with different levels of intake of different nutrients in one or more unit periods of time, given the initial status of these features and the environment (including efficiency of utilisation). In the absence of reliable information on these aspects, an assessment of magnitude of poverty tends to become an arbitrary exercise. It may be worthwhile to formulate meaningful welfare criteria for a given society incorporating some of its specific socio-econnmic features and then assess the magnitude of poverty, until and unless the desired knowledge on the nutritional and health systems is available to facilitate any objective assessment of nutrition requirements.

To sum up, the state of knowledge is thoroughly inadequate to prescribe the minimal nutrition requirements for different types of individuals. Also, the alternatives suggested by some for correcting requirements are based on weak foundations and are unacceptable for the purposes of policy planning and aimed at betterment of nutritional status of the affected sections of the society. The estimation of magnitude

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of poverty can at best be guided only partially by the nutrition norms. Further research work on the relevant issues in nutrition science is urgently called for.

Despite the lacunae discussed in this section, we needd to proceed with the available information for the purposes of practical planning for nutritional development, pending further refinement of the specification of nutritional requirements. Accordingly, the next section summarises the conventional specifications regarding the nutrition requirements for different categories of persons.

2.5 Conventional Nutrition Requirement Specification

Energy Requirements:

The energy requirement of persons is defined as the energy intake that is considered adequate to meet the energy needs of the average healthy person in a specified age/ sex category. The requirement includes: (a) energy for body processes—for basal metabolism, maintenance of body temperature, and synthesis of new tissues; (b) energy for physical activity, and (c) energy for specific dynamic action of foods. The sum total of energy costs needed to maintain the total body content of heat is called energy for maintenance and is experimentally found to be 1.5 times the energy needed for basal metabolism (1.5 X B. M. R). The energy requirements of individuals depend upon (a) age, (b) sex, (c) body size and composition, (d) physical activity, and (e) climate and other ecological factors.

In devising the scales of energy requirements, the methods used are: (1) observation of actual calorie consumption —it being assumed that the quantity of food eaten by healthy people, individuals as groups living a normal life represents their requirements, (2) by calculating factorially the actual

daily expenditure of typical individuals (reference man/woman) by adding estimates of expenditure during so many hours of sleep, work, and recreation, (3) combination of the two.

The reference man and woman are arbitrarily selected convenient starting points for extrapolation. They are a man and a woman aged between 20 and 39 years who are adequately clothed and housed so that the air surrounding the body is comfortably warm (the micro climate is thermally neutral). They consume an adequate, well balanced diet and are neither gaining nor losing weight.

The FAO/WHO Committee (1973) recommend the same average energy requirement from the ages of 25 to 39 years. Energy requirement is to decrease by 5 per cent for each decade between the ages of 40 and 59 years and by 10 per cent from 60-69 years, and for age 70 and above, a further reduction of 10 per cent. The Committee states that the requirements for both energy and protein should be related to the expected weight for height of the adult population, and the mean weights of the different age groupings (20-39, 40-49, and so on) are taken to calculate the energy requirement. The FAO/WHO Expert Group (1975) suggests that the body weight for all ages of adults should be taken as that for the 25 year olds, when this is known, as there is no sufficient information about the extent of change in body mass with aging.

Weight is used as the basis of reference for computing the energy requirements for infants and children. The energy requirements of infants during the first six months of life can be estimated from the observed intakes of breast-fed infants growing normally. The estimated requirements are shown in Table 2.2. For children, the FAO/WHO Committee recommended energy intakes were based on the consumption data on healthy children, as shown in Table 2.2. The I.C M.R. Nutrition Expert Group (NEG) (1968) figures are also shown. The FAO/WHO Committee recommend that in a community

Table 2.2: Recommended Intake of Energy

Age in years	FAO/WHO (1973)		ICMR			
			1968		1981	
	Body weight Kgs.	Energy K. Cals	Body weight Kgs	Energy K.Cals	Body weigth** Kgs	Energy K.Cals
Children						
Less than 1	7.3	820	—	100-120	—	650
1—3	13.4	1360	N.S.	1200	12.0	1220
4—6	20.2	1830	,,	1500	18.9	1720
7—9	28.1	2190	,,	1800	26.4	2050
Male adolescents						
10—12	36.9	2600	,,	2100	34.3	2420
13—15	51.3	2900	,,	2500	47.0	2660
16—19	62.9	3070	,,	3000	56.5*	2820
Female adolescents						
10—12	38.0	2350	,,	2100	36.5	2260
13—15	49.9	2490	,,	2200	45.5	2300
16—19	54.4	2310	,,	2200	50.0*	2000
Adult man (Moderately active)	65.0	3000	55.0	2800	55.0	2800
Adult woman (Moderately active)	55.0	2200	45.0	2200	45.0	2200
Pregnancy (later half)		+350@	—	+300@	—	+300@
Lactation		+550@	—	+700@	—	+700@

N.S. = Not specified

* For age-group of 16—18 years

** Actual weights of well-to-do children from Public Schools

@ In addition to normal requirements.

where a significant proportion of children are underweight because of previous malnutrition, the intention should be to provide for a catch-up growth and a return to normal height and weight, and, therefore, the desirable weight for the age should be used to calculate the energy intakes up to the age of puberty (13 years). The later FAO/WHO Group (1975) has recommended that this should be continued throughout the ages of 16-19 years, as it is a biological fact that growth may occur until the age of 20 years or even longer.

The FAO/WHO Committee has reported, for pregnancy taking, an increase of 20 per cent in basal metabolism in the last trimester of pregnancy, at a figure of an additional 150 calories per day in the first trimester and 350 calories per day in the second and third trimester. ICMR (NEG) (1968) has taken the figures of 5 per cent, 5 per cent, and 12 per cent increase in B.M.R. in the first, second, and third trimester respectively, in Indian pregnant women; and arrive at a figure of 300 calories additional need per day in the latter half of pregnancy.

For the lactating mothers, the FAO/WHO Committee suggest a requirement of an additional 550 calories/day taking into account: (1) an average of 850 ml. milk secreted per day, (2) the calorie content of 0. 72 calories per ml, milk, (3) the effciency of conversion of food calories into milk calories as 80 per cent and (4) the fat reserves laid down during pregnancy. The ICMR arrived at a figure of 700 calories per day as additional allowance by considering (1) 26 per cent increase in B. M. R. during lactation, which accounts for an additional 200 calories per day; (2) 400 calories per day secretion in milk in Indian women, which on taking the efficiency of conversion as 80 per cent, amounts to 500 cals/day additional allowance. The FAO/WHO Committee's recommended intake is the latest figure and can be used for the Indian women with increased intakes for mothers who have less stored fat as a result of inadequate diet during pregnancy.

Protein Requirements

The FAO/WHO Committee has recommended safe levels of protein intakes, necessary to meet the physiological needs and maintain the health of nearly all individuals in a specified age/sex group. This protein requirement $\bar{}$ is defined at the level $m+2\bar{}$, where m is the average requirement, the standard deviation among individuals of the specified age-sex group and is expected to cover the requirements of all but a very small proportion of the population.

There are two physiological approaches to the problem to estimating nitrogen requirements for man. The factorial methods is based on the estimation of the obligatory nitrogen losses, (the amount of nitrogen in the urine, faeces, sweat, etc, when the diet contains no protein) and of the amounts of nitrogen needed for the formation of new tissue; during growth or pregnancy or for secretion in milk. The second approach is based on the measurements of the minimum nitrogen intake needed to maintain nitrogen equilibrium in adults or satisfactory growth in children.

The estimates of average requirements adopted for adults and children are the factorial calculations corrected by a factor of 1.3, that is, increased by 30 per cent in recognition of the fact that even with an excellent protein source, such as milk or egg, larger amounts of nitrogen are needed to secure nitrogen equilibrium or maintain growth than the amount calculated by the factorial method. The same factor was used in estimating the additional nitrogen needs in pregnancy and lactation. For infants less than six months of age, the recommendations are based solely on the observed intakes of healthy infants fed ad libtum. To these estimates of average physiological approach requirement, allowance for individual variation is added. The Commmittee concluded that the requirements for maintenance and growth, including pregnancy and lactation, have about the same co-efficient of

variation (approximately 15 percent). This range of variation includes the technical error, differences among individual and differences in one individual from one period to another. The maior portion was judged by the Committee to be attributable to biological variability. A value that is 30 per cent(2—)above the average was considered to meet the needs of the great majority of individuals. The factor 6.25 is then applied to convert the safe levels of nitrogen intake to safe levels of protein intake, expressed in terms of egg and milk protein, and not in terms of a hypothetical reference protein with 100 per cent utilisation as earlier recommended (FAO/WHO - 1965). Correction for protein quality based on a knowledge of the total diet consumed, should be applied to all groups, except breast-fed infants. The safe level of intake of food protein would be predicted from the formula:

$$\frac{\text{NPU of egg or milk}}{\text{NPU of test food}} \times \text{Safe level of intake of egg or milk protein}$$

In the Indian dietories, NPU value of 65 per cent has been considered reasonable for use in computing protein allowances (ICMR Committee, 1965). The protein requirements in pregnancy have been computed by the FAO/WHO Committee from the nitrogen retention found in nitrogen balance studies conducted over long periods of pregnancy. The additional protein needed by the lactating woman is computed from the volume and composition of the milk secreted. For lactation, the committee considered a volume of 850 ml. milk per day with an average of 1.2 g. of protein per 100 ml., so that the average daily secretion is 10g. of protein or 1.9 nitrogen per day. This is used for computing the recommended intakes. No correction for efficiency of conversion of dietary protein to milk protein is considered. The ICMR Committee (1968) had earlier arrived at a recommendation (for Indian women) of 20 gm/day, considering NPU of Indian dietories, 50 per cent conversion efficiency and milk output of 800 ml/day. The upper limit of milk output (800 ml/day) should be used for correction of the FAO/WHO recommended

intake to arrive at a suitable allowance for the Indian women. The requirements of ICMR and FAO/WHO Committees are shown in table 2.3.

Protein-energy ratios have been calculated in a variety of ways, without firm agreement as to either the correct way of calculating such ratios or the proper use of such ratios, if calculated. The FAO/WHO Group (1975) defined a "safe" protein-energy ratio to be one that would be expected to meet the protein needs of almost all the individuals when their energy needs have been met.

Earlier, Platt, Miller and Payne (1961) proposed an adequate dietary ratio which was the ratio of the recommended intake for protein to average energy requirement. This can be criticised on the grounds that an individual who had lower than average energy requirements would eat less of the diet and if he did not also have lower than average protein needs, would become deficient. In fact, to the extent that energy requirements vary because of differences in physical activity, protein requirements also very but not proportionately, so that it is clear that we should use a figure less than the average requirement in order to calculate a safe level for the ratio protein- energy in an adequate diet.

The protein-energy ratio is calculated as under : If any individual is consuming E K calories per kg. body weight per day and has a mean protein requirement $\overline{PR}$, the percentage of calories which should be derived from protein in an adequate diet for that person is $K-\overline{PR}/E \times 400\%$. If a person changes his energy intake in response to a change in a activity then clearly K will also change in inversely proportional way assuming $\overline{PR}=0.89$ gm/day then the values of K corresponding to various energy intakes take the form of a downward sloping curve. Every point on the curve describes a diet composition and a daily intake which will just provide the average protein requirement. All the points above and to the right of

the curve will provide more than this amount and all points belowt he curve less. Two questions arise : (a) What about the individuals who need more protein than the average?; (b) What is the lowest possible value of energy intake ?

The first can be answered by constructing a similar curve using the value PR + 30%, that is, the safe level of protein requirement, instead of the average. The second question, as discussed earlier is difficult to answer.

Beaton and Swiss (1974) taking an estimate of variability of requirement of 15 per cent, defined the lower limit of energy intake as the mean requirement minus 2 standard deviations. Joy and Payne (1975) consider the average energy requirement suggested by FAO/WHO to be the lowest energy intake which could meet the requirements of any individual for maintenance, growth, and activity. This requirement also has individual variability, which was assumed to be the same as for BMR (between 6-7 per cent) and this suggests a range of $\pm$ 13 per cent (as seen in figure 1). Therefore, for a child at the lower end of this range of energy needs, and at the same time having the upper range of protein needs (analogous to point M in figure), the protein-energy ratio would be about 6.9 per cent. The probability of this occurring is, however, small (perfect negative correlation of protein and energy requirements). A degree of positive correlation is expected. An upper limit for a minimum energy requirement was not established and the approach does not take into account the likelihood that protein deficiency may in many cases be the consequence of energy insufficiency in individuals unable to adapt to the lowest extent of the range. The figure indicates that the area below and left of the line RML defines diets likely to cause protein-energy malnutrition and there is very little likelihood of protein deficiency in 2-3 year olds who are consuming diets with little over 5 per cent of the calories derived from egg or milk protein or of equivalent levels of other protein sources.

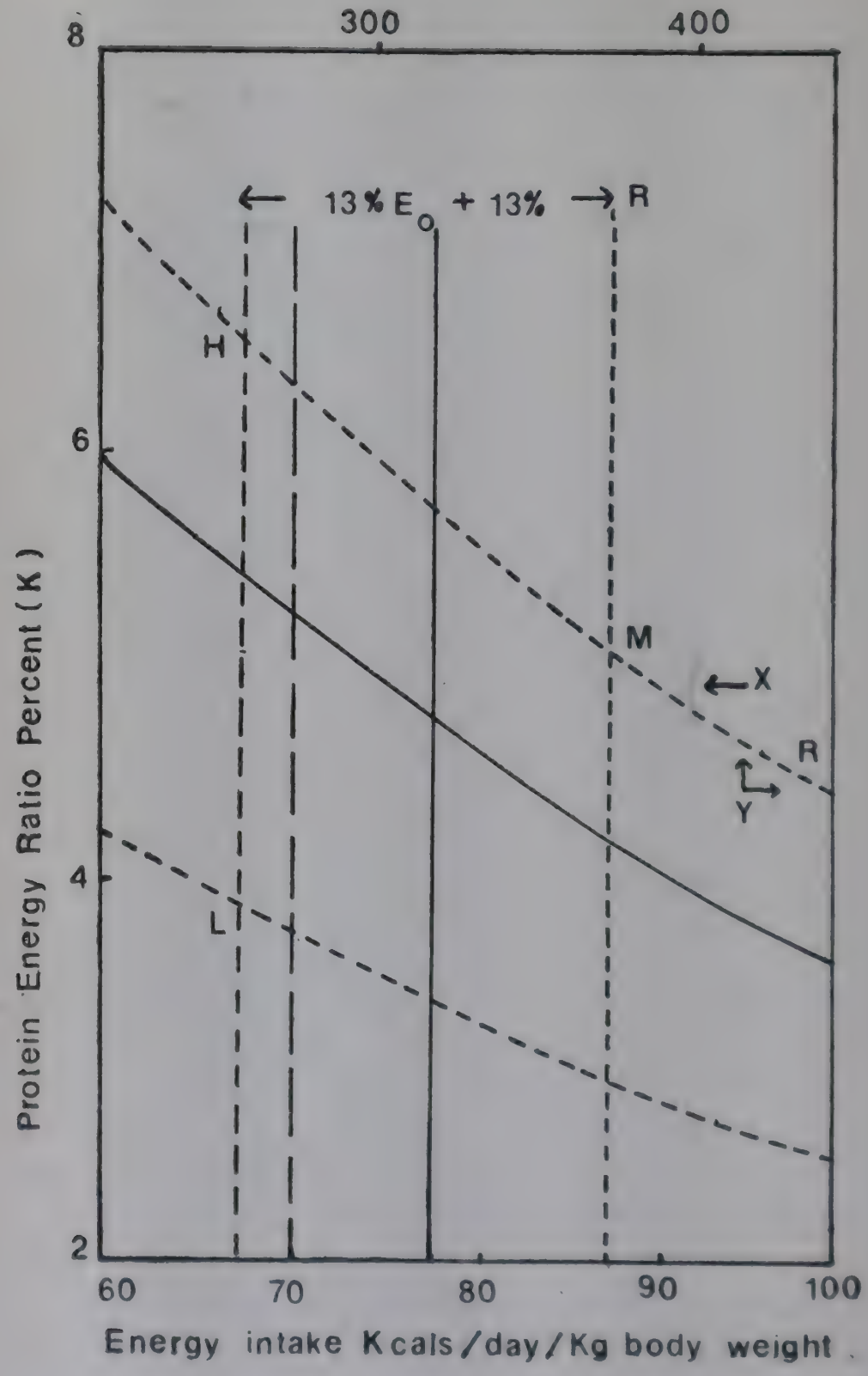
300
400
8
6
4
2
← 13% E0 + 13% → R
H
M
L
← X
R
Y
Protein Energy Ratio Percent (K)
60
70
80
90
100
Energy intake K cals / day / Kg body weight

Fig 1,.

The FAO/WHO Group has suggested that for individuals or population group categorised as having "moderate terms used in the activity" in the 1973 Report. a protein concentration of 5-5.5 per cent of energy would suffice to meet the needs of almost all individuals who met their energy needs; where activity levels are categorised as light, a somewhat higher ratio would be needed to provide sufficient protein; similarly where activity levels are classified as heavy, a lower level might suffice. Exceptions to this generalisations, may be the young infant, the pregnant and lactating women. In the absence of information about variabilities and correlations of requirements for these groups, no recommendation about safe protein-energy ratios can be offered ; the ratios are unlikely to be lower, and may be higher. These safe-protein energy ratios are intended only for the assessment of the diets of individuals and not appropriate for comparison with national or average diets. As they are based upon predictions of the concentrations required to meet physiological needs, these should be seen only as a lower limit of acceptable dietary concentration, below which the risk of physiological inadequacy increase.

Fat Reuqirement

The ICMR Committee (1968) suggest a daily intake of 15 gms. of visible fat in the form of vegetable oils to satisfy the minimum essential fatty acid requirement and suggested that it is desirable that not more than 30 per cent of dietory calories should be derived from fat.

Mineral Requirements

Calcium :

The minimum requirement of calcium was defined by the FAO/WHO Group (1961) as the smallest amount of that nutrient which will maintain health and keep the body in calcium balance over a period of years when the diet is otherwise adequate and the vitamin D status of the body is

satisfactory. The requirements have been estimated by diet survey data and calcium balance studies, and on the basis of these studies the FAO/WHO expert committee (1961) recommended a range of figures for each age/sex/physiological status/group (Table 2.3). The same figures have been recommended for the Indians by the ICMR Committee (1981). During pregnancy a retention of 300 mg. calcium/day has been indicated, and losses in milk also amount to the same. Taking into consideration the wide individual variations in absorption and the retention of dietary calcium, an intake of 1 mg. of calcium has been recommended by ICMR (1981). The FAO/WHO Committee (1961) has recommended a range of 1.0–1.2g/day, but the lower level as recommended by ICMR (1981) will suffice for the Indians.

Iron :

The recommended intakes of iron are based on the (1) estimates of physiological losses of iron from the body and of increments in body iron during growth (factorial approach). and (2) estimates of iron absorption from different foods and in the presence of different foods. The FAO/WHO (1970) recommendations are based on the estimates of losses in adult man, of 0.9/mg. per day which is revised to 6-9 mg per day. taking absorption of dietary iron to be about 10-12 per cent. On the basis of studies on the Indian adult men, the ICMR (1981) estimated an average loss of 1.7 mg/day. With 20 per cent allowance for individual variability and terms of dietary iron (10 percent absorption in Indian dietories) an intake of 20-25 mg/day was recommended. Menstrual loss was found to increase dietary iron requirement by 10 mg/day (ICMR 1981).

Based on Apte and Venkatachalam's (1963) estimation of iron loss during pregnancy, the ICMR Committee (1981) computed an average loss of 1.5 mg/day and allowing for 20 per cent individual variability and 10 per cent absorption efficiency recommended 40 mg. (total) for the pregnant women.

Accounting for iron secretion in milk, (0.12 mg/100 ml) the requirement figure arrived at by the ICMR Committees was 30 mg/day for lactating non-menstruating women, and 35 mg/day when menstruating. The FAO/WHO (1970) Committee report that for women whose iron intake throughout life has been at the level recommended by them, the daily intake of iron during pregnancy and lactation need not be increased.

Requirements of Vitamins

The term vitamin requirement can be defined either as the amount of the vitamin necessary to maintain a certain level of the vitamin or its metabolities in the blood or urine.

Vitamin A

The FAO/WHO (1967) figures are given in Table 2.3 along with the ICMR Committee (1981) recommendations. The ICMR (1981) recommendations adopted the same vitamin A allowances suggested by the FAO/WHO Committee in the absence of reliable data on vitamin A requirement for the Indians. As the vitamin A needs for foetal growth is small the FAO/WHO Expert Group (1967) did not recommend any additional allowance during pregnancy. Depending on a milk output of 850 ml/day, and the concentration of vitamin A in milk, an extra allowance of 450 μg has been suggested by the FAO/WHO Group (1967) while taking the higher range of milk output of 800 ml. for the Indian nursing mothers, the allowance recommended becomes 400/μg. The requirement in being expressed in terms of β–carotene for the Indian dietaries takes into account the efficiency of absorption of β-carotene, as well as the efficiency of absorption of carotene has been considered to be only 33 per cent by the FAO/WHO Group (1967) and taking theoretical conversion-ratio of β carotene to vitamin A as 0.5, FAO/WHO suggest 6 mg. of dietary β-carotene to be equivalent to 1 mg. retinol. However, studies on the Indian Dietaries (Rao and Rao 1968), Lal and Reddy (1970, have suggested greater absorption and

the ICMR Committee (1981) has assumed an average of 50 percent absorption so that the factor for converting carotene to retinol values for the Indian diets will be 0.25. Allowances for losses of vitamin A have not been considered as β-carotene, is not so susceptible as retinol to cooking and processing losses.

Vitamin D

The requirement level is the amount of vitamin required to prevent rickets and to permit maximal retention of calcium when calcium intake is satisfactory. Although children must be able to synthesise vitamin D in the skin due to frequent exposure to the sun in tropical countries, yet the high incidence of rickets in the tropics indicate that this is not sufficient and that some amount of dietary vitamin is also essential. The level indicated by ICMR (1981) was an arbitrary one, tentatively suggested due to insufficient data on the Indians and the recommendations were 200 I.U. for all categories, assuming that out of 400 J.U., recommended by NRC (1964), half will be obtained from sunlight by the Indians. The FAO/WHO (1970) group suggested a higher intake of 10 mg. (400 I.U.) cholecalciferol for infants and young children, and pregnant and lactating mothers and 2.5 mg. (100 I.U) from age 7 onwards, on the basis of a study by Perera and Reddy (1971).

Vitamin E

The FAO/WHO Group has not given recommendations for this vitamin. A tocopherol requirement of 10-30 mg/day has been suggested by NRC, the upper level representing the need when the diet contains a high level of polyunsaturated fatty acids. Other antroxidants such as ascorbic acid, or a trace element, selenium, can reduce part of the requirement for this vitamin.

Vitamin K

No recommendetions have been given as dietary deficiency is not believed to be a problem.

Vitamin C

The minimum requirement has been taken to be the intake that prevents the development of deficiency disease, scurvy (FAO/WHO 1970) report that there is adequate evidence from experiments and field studies that a daily intake of 10 mg not only provides protection against scurvy but is sufficient to cure the disease. On this basis with a large margin of safety for losses in cooking and preparation, the recommendation was held at 30 mg/day for adults, and 20 mg for children. Applying an individual variability factor of 20 per cent and losses of 50 per cent on the figure, a requirement of 50 mg/day for adult was arrived at by the ICMR Committee. No additional allowance has been suggested by FAO/WHO for lactation, whereas ICMR recommends an additional 3 mg/day to replenish lossess in milk. As there is not much evidence proving the beneficial effects of additional dietary vitamin C on the content in milk, the figures of FAO/WHO (1970) which is the more recent report can be considered more relevant for Indian purposes also.

Thiamin

As the thiamin requirement is related to the total energy content of the diet, it is expressed on the basis of amount of vitamin required per 1,000 calories. The FAO/WHO (1967) Group on the basis of field studies reported that persons on a diet containing more than 0.33 mg/1 000 cals. excrete the excess in the urine as there is no provision for storage of thiamine in the body and therefore including a safety margin to cover individual variations, recommended 0.4 mg/1000 cals. The ICMR Committee based its figures on urinary excretion studies and transketolase activity and arrived at a figure of 0.2 mg/1 000 cals as the minimum requirement. With 20 percent individual variability, and allowing for 50 per cent cooking losses in the resultant figure, a figure of 0.5 mg/1,000 cals was arrived at. As little evidence is there to show that requirements expressed per 1,000 calories differ for children, the same requirements are used, and as it is not possible to

give any precise indication of the physiological cost of pregnancy and lactation, the same allowance of 0.5 mg/1,000 cals is recommended. The ICMR recommendations based on studies on the Indians is more relevant for our purpose.

Riboflavin

The recommended intake is related to the dietary energy intake. The FAO/WHO (1974) report on dietary studies that a daily intake of 0.5 mg/1,000 cals, with allowance for individual variability gives a recommendation of 0.6 mg/1,000 cals. The ICMR committee in estimating the requirement in the Indian subjects recommend 0.55 mg/1,000 cals for, all age-groups and also during pregnancy and lactation.

Niacin

A figure of 5.5 mg niacin equivalents[17] per 1,000 calories was accepted by the FAO/WHO Group (1965) as the physiological requirement. With an allowance of 20 per cent for individual variability, the requirement figure becomes 6.6 mg/1,000 calories. This figure corresponds to intakes in the Indian populations in whom incidence of pellagra is rare, and therefore this is adopted for the Indians too by the ICMR Committee. When the protein intake corresponds to the recommended allowance, it is assumed that the contribution of tryptophan towards niacin nutriture is normal and the conversion factor of 60 mg. tryptophan=1 mg. niacin, held to be good under different dietary and physiological conditions. Additional need during pregnancy and lactation and for infants and children is met by additional allowance corresponding to the calorie allowance in the diet.

17. Niacin equivalents = Niacin (mg) + $\frac{\text{Tryptophan (mg)}}{60}$

Vitamin B_{12}

Recommendations are based on (1) production of haematological response in deficient patients, (2) intake needed to compensate daily losses. Although it is reported that as much as a 0.1 mg. parenteral dose of vitamin B_{12} can produce a haematological response in deficient patients, yet the knowledge of the absorption of vitamin B_{12} in foods, the cooking and processing losses, effects of stress on requirements etc., is so meagre, that the safety factor added to the minimum requirement is considerably large.

Inclusive of individual variations, the FAO/WHO (1970) Group recommended 2 μg/day for adults. The ICMR Committee recommended a modest 1.0 μg per day, due to the difficulty in achieving in the Indian dietaries high intakes of vitamin B_{12}, which is entirely derived from foods of animal origin. To provide for foetal storage and milk secretion, the allowance for pregnant and lactating mothers is given as 1.5 μg of vitamin B_{12}. Vitamin B_{12} allowance for infants is at the level of 0.2 μg/day, while for children it is suggested to be between 0.5 1μg/day, by the ICMR Committee. The FAO/WHO figures are slightly higher.

Folic Acid

The FAO/WHO Committee (1970) admit that there is difficulty in assessing the folate content of foods and in making recommendations for dietary intake. The extent to which the different forms of folate can be absorbed from the intestine and made available is also not known. Based on the observations of the dietary intakes in populations, the ICMR Committee suggested that a diet containing 100 mg. free folic acid may be adequate to meet the folic acid requirement of an adult. The FAO/WHO Committee has placed the recommendation at a higher level (200 μg/day) which, it admits, may be proved later on to be too high. Folic acid requirements in pregnant and lactating states are not known with certainty.

The recommended figures of the ICMR Committee and the FAO/WHO Committee are shown in the tables. They are based on very limited data and are quite arbitrary in nature. The requirements for other B-complex vitamins have not been specified by both the FAO/WHO and ICMR Committees. Deficiency states of these vitamins are rare and nutritional problems do not arise.

3

Demand for, and Supply of, Nutrients

A. Demand for Nutrients

In this chapter, we briefly review the literature on consumer demand analysis and suggest the framework relevant from the demand sub-system for the Integrated Models. The demand for nutrients is of two types : (i) physiological (normative from biological view) ; (ii) behavioural (broadly governed by socio-economic factors). The first is already discussed in Section 5 of Chapter 2. In case of the second when we try to obtain demand for nutrients, it is done via demand for food items. Again the demand for food items can be obtained in two ways :

(a) least cost balanced diet (this is normative, assuming the knowledge of nutritional composition of food items and physiological minimal requirements of nutrients, the consumer is assumed to arrive at a selection of commodities and their quantities so as to satisfy the nutritional requirements at least cost)

(b) statistically observed behavioural relations (from the past data we obtain the relative influences of various parameters like prices, income, etc, on the demand for various commodities and thus derive the structural behaviour which can estimate the demand whenever these parameters are known.

3,1. Survey of Demand Analysis

Both static and dynamic aspects of consumer demand have been studied by many economists and guidelines have been provided for empirical (research) work. The survey of

Houthakker [18] deals with the theoretical issues of consumer behaviour. A recent survey of Barten[19] emphasises the need for simultaneous estimation of the demand for commodities. In the traditional way of demand estimation, Engel curve analysis is the starting point and Engel elasticities will be obtained by regressing the income or expenditure on consumption. In general, double log, semi-log, log-inverse and log-log-inverse forms will be appropriate when single commodity models are considered for food commodities and these forms are presented below.[20]

		functional form	coeff. of elasticity
1	double-log	$\log y = a+b \log x$	b
2	Semi-log	$y = a+b \log x$	$\frac{b}{a+b \log x}$
3	log-inverse	$\log y = a-b/x$	b/x
4	log-log inverse	$\log y = a-b/x-c \log x$	$b/x-c$

where

Y = Consumption (in value terms or quantity terms)

X = Expenditure or income & a, b, c are parameters

To arrive at the aggregate demand one has to project the population apart from the income. If per capita estimates of demand were available for each economic class and demographic group, then forecast of population were to be made with certain assumptions about mortality and fertility trends. To arrive at the population size in different economic groups, the assumptions in respect of income distribution are necessary. The aggregate demand can be obtained by multiplying

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18. Houthakker H. S. The present state of consumption theory. *Econometrics* 1961,2,4(pp.704-40)

19. Barten. The systems of consumer demand functions approach : A review. *Econometrica* January 1977,45 (1).

20. Some of the FAO studies found these forms more suitable for estimation purposes. For simplicity one may, however, take the linear forms.

the estimated average per capita demand with total population or per capita demand of a specification group with the corresponding projected population and summing the estimates overthese groups.

Lancaster[21] spelled out a new approach to consumer demand analysis, in which the demand for goods is obtained via the demand for a set of characteristics associated with the goods. The relationship between goods and characteristics was assumed to be objective rather than preferential. The preferences exist for the bundle of characteristics. The progress on empirical work in India was not much due to data problems on the relevant characteristics. Bhattacharya[22] discussed the different studies on the consumer behaviour in India where he pointed out the practical problems and limitations of different methods, including data. All these studies are based on statistical estimation of expenditure/income elasticities and price elasticities using either time series data or cross-section data. Assuming some trends of income/expenditure, relative prices and population, the future demand for food commodities will be estimated. So the level of demand can be altered using the policy instruments, such as income distribution, relative prices, and growth of population.

Fluctuations in demand for nutrients can be explained by changes in income levels, prices, preferences, traditions, health, age, sex, etc. Attempts have been made by Perisse *et al*[23],

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21. Lancaster, Kelvin. Consumer Demand : A New Approach. New York Columbia Univ. Press, 1971.

22. Battacharya N. Studies on Consumer Behaviour in India. (un-published), 1974.

23. Perisse J, Sizaret F, Francois P. The effect of income on the structure of the diet. *F.A.O. Nutrition News letter*, 1969. 7(3).

Francois[24], and Levinson[25]. The objective of the study undertaken by Perisse and others is to find out the structural changes in diet when income increases. Francois's emphasis is to study the effects of increases in income on the protein structure of the diet. Levinson's study deals with the identification of the determinants of malnutrition among the young children below the age of two years in rural Punjab. Regression analysis is the common technique in these studies. Perisse et al[26] and Francois approach considered income as the only explanatory variable, whereas a multiple regression analysis is adopted by Levinson. Francois's analysis atempted to fit Engel curves with the data on a rural community of law income rice-consuming country. Levinson approach is rather comprehensive and he carried out the analysis for children belonging to different socio-economic groups. Besides regression, frequency distribution approach is considered by Francois to determine the income levels at which quality of diet changes. Details of each of these empirical studies are given below.

All these studies identified income as a major influencing factor of nutritional status. Perisse *et al* and Levinson observed that the proportion of calories supplied by carbohydrates decline as income increases and the intake of more expensive animal or vegetable products increases. Perisse *et al* found that increases in income will be followed by rise in consumption of separated fats (oils, butter, etc), unseparated

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24. Francois PJ. Effects of income projection on the protein structure of the diet. *Nutrition News letter* 1969, 7 (4), pp. 1-15.

25. Levinson FJ. The economic analysis of the determinants of malnutrition among young children in rural India. [Ph.D. dessertation]. Cornell University, 1972.

26. Perisse et al study is based on a cross-section data on 85 countries. The percentage of calories from fats, animal protein as a per cent of total calorie intake etc. are the dependent variables chosen and the data base are food balance-sheets and per capita incomes of different countries.

edible animal fats and fall in the intake of unseparated vegetable fats (cereal, nuts, and oilseeds).

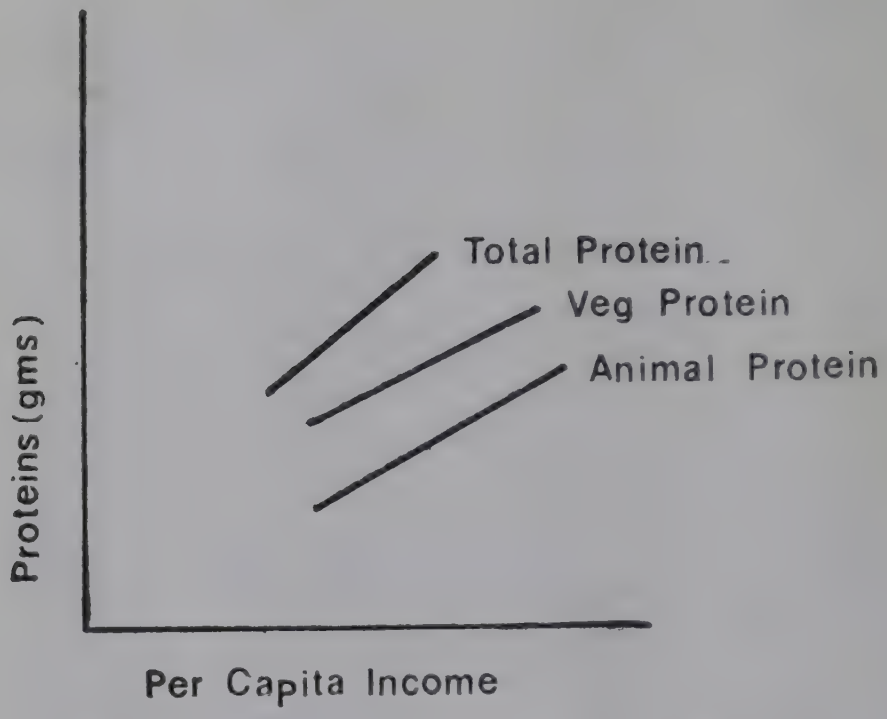
Some of the regression results have been presented in table 3.1.

Table 3.1 : Regression Results

Dependent variable	Constant term	Regression coeff. of income	Correlation coefficient
% of cal. from fats	–19.87	7.59	0.84
Animal proteins as a % of total calorie intake	–5.58	1.7	0.77
Veg. proteins as a % of total calorie intake	16.02	–1.57	0.74
Total proteins as a % of Total calorie intake	10.44	0.13	0.82

The main assumption in the study of Francois is that protein intake has a positive correlation with income and he attempted to study the share of high quality proteins in diet when income rises. Log-inverse form for calories and semi-log form for proteins, animal proteins and vegetable proteins provided better explanations with income as independent variable except for vegetable protein.

The relation between protein intake and per capita income has been depicted in Fig. 3. 1. However, Francois noticed that in low income countries both quantity and quality will be stable and assumption of significant increase in per capita income will be too optimistic since population growth rate and prices will absorb a significant proportion of income rise.



The Levinson study confined to the specification of variables in the determination of nutritional status of child. He conducted a survey on 496 children belonging to different socio economic groups and using anthropometric measurements, he identified the incidence of protein calorie malnutrition of different degrees among the selected subjects. The incidence of PCM is rare in (children of) socially and economically upward class. He noticed substantial deficiency in calories and iron among them. He attempted to study the impact of nutritional intake, income, sex, infection, etc., on nutritional status of the children, and intake of calories, sex have significant influence on the nutritional status. Infection as a function of economic status, family size, sex and nutritional intake has been studied, but these relations have low explanatory power.

3.2 Aggregation and Disaggregation Problems

The estimation of demand for various sections of the population classified by economic classes or socio-economic classes can be done by the usual methods via single commodity models or via simultaneous estimation (for multiple commodities) models. However, when we break up the population on the basis of age-sex groups, etc. the identification of behavioural parameters in the demand relations is a difficult exercise, both for reasons of conceptualisation and availability of information. Since the consumption in the early age-groups is governed by the characteristics influenced the consumption decisions of the family unit, estimation of demand for these segments of population needs behavioural assumptions regarding intra-family distribution in consumption and also regarding relative influences of the various parameters like changes in prices, income, etc. Accordingly, forced by data limitations, one has to resort to aggregation of demand for various segments of population.

Various types of functional classifications are possible. Depending upon the purpose of the analysis and availability of relevant data, specific types of aggregations/disaggregations can be taken up. In general, the following categories of disaggregations are possible : (i) regional basis : districts, agro-climatic or other regions, rural, urban, etc; (ii) income classes in different ranges; (iii) professions/occupations; (iv) sex; and (v) age-groups, infants-mothers, pre-school children, adolescents, adults.

Whenever we are attempting a specification of the demand for food for various age-sex groups, we have to take the family income as an important parameter and make assumptions or separately investigate the behavioural characteristics involved in intra-family distribution.

If we segment the population on the basis of socio economic classes, the behavioural specification of demand

function is easier but we shall not be able to prescribe the nutritional requirement for each of the classes on physiological or normative Considerations. On the other hand, if we classiy the population on the basis of age-sex- occupation, the normative prescriptions are easier to specify, whereas identification of behavioural relation is difficult. One has to compromise between the two, depending upon the availability of relevant information.

The relation between individual and aggregate consumption function is discussed by Friedman. [27]. The behaviour of the community can be described from individual relation, if the same functional relation, holds good. In deriving aggregate demand function, one has to consider the distribution of consumer units by the variables in the relation. Hicks, [28] Houthakker and Taylor, [29] and philips [30] viewed that the error involved in the aggregating problem is of little importance. Under homogeneity of degree zero condition the properties for the individual equations carry over to the aggregate equation obtained by summation over the individuals. The aggregate demand function depends upon the distribution of income and family size, given the household demand function. The aggregate demand function has been estimated under the assumptions of constancy of income distribution and average size of the family by Tobin [31].

For the purpose of the Integrated Models, we take up linear forms of demand functions for computational simplicity. In one of the models (4-stage model) the estimation of demand relations is needed only at the aggregate level consumer level demand is derived as the normative least cost

27. Milton Friedman. *Theory of the Consumption Function* New Delhi, Oxford and IBH,1970.
28. Hicks A *Revision of Damand Theory* London, Oxford University Press, 1955.
29. Houthakkar, Taylor *Consumer Demand in the U.S.* 1929-70, Harvard University Press, Cambridge, Mass., 1970.
30. Philips. L *Applied Consumption* North-Holland/American Elsevier, 1973.
31. Tobin J. A statistical demand function for food in the US. JRSS 1950. Vol. CXIII,

balanced diet. When we have to specify age-group/occupation specific demand, the behavioural approach needs to be suppressed by physiological approach–the demand function may be expressed only in terms of quantities of commodity requirements and/or nutritional requirements.

B. Supply of Nutrients

Given the demand for nutrients, it is necessary to evolve effective intervention strategies in terms of price incentives, etc, in the supply system in order, at least, to match the demand. For this purpose, it is necessary to examine the main determinants of nutrient supply, for instance, production of agricultural and non-agricultural food commodities.

3.3 Agricultural Production

In India, agricultural commodities are the major sources of supply of food as well as nutrients. Agricultural productivity depends on such factors as prices of various commodities, the availability of fertilisers at reasonable prices, technology, etc. Presently, both traditional and modern ways are employed in agricultural production. Modernised agriculture includes the usage of inputs, such as high-yielding varieties, fertiliser application, irrigation, etc. The quantity of yield and nutritional content of unit item per unit area per annum are the major considerations determining the supply of nutrients.

Sivaraman[32] stressed the need for popularising the scientific agriculture to improve the nutritional status of rural families. A self sufficiency in food produced from ones own land need not necessarily lead to a balanced diet for the family. The main stress in modernised HYV agricultural production was on cereals, such as rice and wheat. Coarse cereals and pulses seem to be generally neglected. Production shifts are in favour of rice, wheat, and commercial crops as indicated in Table C. 3 (Appendix C).

32. Sivaraman B. Nutrition in rural India in the Fifth Plan. *Proceedings of Nutrition Society of India 1974*, No. 17, pp. 8-12.

The growth rates of coarse cereal except bajra has tended to decline over the sixties and during the Fourth Plan period. Further observations were made by Panikar [33] that production and prices pattern is gradually tending towards economically better sections, since poor men's traditional food items like jowar, bajra, ragi, etc, are becoming costlier and scarce. He further observes that the all-India wholesale price index number (1961-62 = 100) of jowar, maize, and barley are 241.6, 237.6 and 242.0 in 1972-73, as against 231.2 for rice and 222.5 for wheat. Policy intervention is essential to effect the nutritional status of socially and economically backward sections by ensuring the consumotion at controlled prices or providing incentives for adequate production and availability at reasonable market prices.

Michael Lipton [34] observed that the type of farm inputs used has also retarded the abilities of poor rural people to afford enough food, and scarce rural land to supply it, in ways beneficial to powerful urban groups. Given the public and private spending on agriculture, it has been allocated excessively to the subsidised provision of inputs which do little for poor people's nutrition, but much for urban requirements of marketed rural raw materials. In a study on 22 less developed countries he observed that barely 20 percent of the total investments reached the agriculture sector in 1950-65 and yet typically engaged 70 per cent of population to make 45 per cent of output, and this neglect of agricultural investment is not on the basis of its returns. This clearly shows that there is a setback in the planning itself giving rise to lesser agricultural produce. It is argued that due to mounting pressures from urban areas, even this inadequate agricultural investment is being mostly misused to cater to the needs of the urban rich. This is done mostly either by

33. Panikar P G K. Recent trends in the production and prices of coarse cereals and their implications for the nutrition status of the economically weaker sections. *Proc. Nutr. Soc. India* 1974, No. 17 pp.55-60.

34. Michael Lipton. Urban bias and food policy in Poor countries. *Food Policy*. November 1975, pp.41-52.

producing export crops (say, commercial crops) or rich man's foods, with scant regerd to the calories output per acre or per unit of investment. Lipton argues that this type of shift in agriculture tending towards lesser production of poor men's food causes lesser calories at the costliest rates, usually out of reach of the poor, especially the rural poor. This conclusion may, at best, be partially valid in some small regions but not in general. Firstly, the market forces determine the allocation of land for one crop or another and if the poor man's food like bajra, etc, is costly then the farmer would shift in favour of producing that commodity provided yield factor justifies it. At present HYVs for millets and pulses are ineffective or non-existent and thus the net production of nutrients per unit land does not justify production of the so called poor man's foods. On the other hand, if the production of major cereals can be stepped up and prices brought down, poorer people will have greater consumption possibility. After all, poor are not attached to inferior cereals/millets because of palatability or things like that. Price mechanism mainly effects their menu. Thus, the issue in production system is how to maximise the quantity and quality of nutrients per unit land per season in a least-cost manner. Governmental subsidies in agricultural inputs whenever desirable will provide the incentive impetus.

We do not propose to go into the depth of this sub-system as the Indian Institute of Management, Ahmedabad (IIMA), has undertaken the study on agricultural production sub-system of Tamil Nadu covering the study of the existing, production relationship within the agricultural economy, the determinants of production system identification of the constraints operating on the agricultural production economy and suggest a desirable production programme.

The main objective of this exercise is to provide the policy-maker some mechanism by which he could *a priori* guage the consequences of the various policy alternatives open to him, or alternatively choose a policy-mix that would

help him achieve the overall nutrition objective in an efficient manner.

3.4. Non-Agricultural Commodities

The non–agricultural commodities include fish, meat, eggs, milk, etc. Though the animal foods are costlier, the major advantage with these foods is that the wastage of nutrients is minimum, that is, most of the nutrients present in these foods are being absorbed by the human body But once again these animal foods, such as meat, fish etc, are usually beyond the reach of poor man.

Further improvement of fisheries, poultry and diary farming will go a long way in strengthening the nutrition position of the future. Milk and egg are the most commonly consumed nutritious foods of the day. A study by Bhote and Jayaraman[35] shows that in Tamil Nadu, the average daily per capita consumption of milk has increased from 77 gms/day in 1951 to 83 gms/ day in 1961. Improving the net-work of dairy farms will enable the proper distribution of the milk. Apart from this, animal husbandry schemes have been introduced to ensure the optimum (improved) yield and better health to the animals. Following the Anand pattern, and adopting the cross-breeding programme of animals, it is worthwhile to develop milk production as a subsidiary industry in the rural areas. The programme should be aimed at the small and marginal farmers by giving the necessary facilities in view of the lack purchasing power in lower income groups in rural areas, as this generates the employment also.

3.5, Specification of Supply Functions

Effective supply S of nutrients is determined by (i) production of various food commodities, (ii) food processing techniques, and (iii) trade (private/govt.) operations in stocking, trade regulations, including imports/exports. If q is the quantity available (q can be a vector if a number of commodities are involved) defined as production I imports/

35. Bhote R.A. Jayaraman S. Trends in milk production during 1956-61. *Agricultural Situation in India*. Vol. 22, P. 663.

exports ± deplenishment / accretion stocks (of individual commodities), Tij the nutritional loss or addition (the latter applies whenever fortification takes place ; otherwise usually loss is inevitable) transformation for individual commodity i with reference to technology j, then

$$\bar{S} = Bq$$

where B is the nutrient transformation matrix

The specification of the production, and estimation of parameters in this system of relations explaining the behaviour with respect to various policy instruments is a separate exercise (See IIMA Study for details) For the purpose of integration of demand and supply and also obtaining optimal intervention programmes from the point of view of a public authority, we need some implicit and explicit specification and assumptions. In general, in implicit form,

$Qj_t = gj(p_{t-1}, p^s_{t-1}, T)$ where Q^j_t is production quantity of j, the commodity, p^j_t price of the commmdity, P^s_t price of substitute crop, T technology (inputs used etc ,) For simplicity, one may assume a linear form of this function. However, an important consideration, as in the estimation of demand, is the need for simultaneous estimation of production parameters. Isolated or single commodity models may lead to errors of disaggregation The response of the supply or acreage allocation have to be studied under the existing institutional set-up. It has been pointed out that in underdeveloped nations these exogenous factors tend to make price response insignificant. The responsiveness of agricultural sector to various Incentives, is a necessary condition for effective framing of agricultural policies; quantification of the functional relation depicting the relative impact of these parameters is necessary.

The price responses are relevant for short-term policies. Long—term changes may be more easily made, however, if new factor and technology may be induced partly through price mechanism.[36] A number of studies have been conducted in this area of supply response and noted are the works of Nerlove,[37] Behrmon,[38] and Rajkrishna.[39] The Nerlovian model analyses the farmers response of acreage to changes in prices.

The Nerloian model is as under :

a) $A_t - a_o + a_1 P_{t-1} + U_t$

b) $A_t - A_{t-1} = B (A_t^* = A_{t-1})$

where :

A_t = Actual acreage

A_t^* = Anticipated acreage

P_t = Actual price and

U_t = Disturbance term

Solving the equation (a) and (b) we have

$A_t^* = b_o + b_1 P_{t-1} + b_2 A_{t-1} + V_t$

where b^0, b^1, b^2, are the parameters to be estimated and V^t is the new disturbance term.

The Behrmen and Rajkrishna's models are the modified versions of Nerlovian adjustment model. The former included a risk factor and the latter has incorporated two additional variables – relative yield and rainfall. Some of these models or modification of these can be made use of.

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36. Minnesota conference on "supply and market relationships in peasant agriculture". Minnea polis, Feb. 18-20, 1966.

37. Nerlove M. *Dynamics of Supply : Estimation of Farmers Response to Price*. The John Monkina Univ. Press, 1958.

38. Behrmon J R. Supply Response in underdeveloped agriculture: A case of four major crops in Thailand 1937-63. North Holland, 1967.

39. Rajkrishna. Farm supply response in India - Pakistan A case study of the Punjab. *The Economic Journal*. 1963, 73 (1).

Specification of production/supply functions needs to be classified into two categories: (i) the function relevant to farm level decision, (ii) the aggreage function relevant to general public intervention programmes. The policy parameters at farm level are generally land allocation for various crops and varieties, thereof, input allocation, etc, and policy parameters relevant to government intervention are generally, quantity and price allocation policies in respect of agricultural inputs, mainly fertiliser and water; support and procurement prices for different agricultural commodities and procurement policies. A classification of farmers (in terms of land holdings/level of technology, etc) should help in formulating the objective functions for each of the classes, so that the policy parameters pertinent to each of these classes be distinguished and incorporated while specifying the supply model. Decision models relevant to farm level should guide the policy intervention at the aggregate level by incorporating the lower levels behavioural features. Policy parameters appearing in the aggregate supply function are used to maximise the total supply of nutrients (subject to certain budget constraints). As a consequence of such optimal decisions, the interaction with farm level decision should be examined and the feedback made use of for revising, if necessary, the broad aggregate level intervention schemes (IIMA Study gives some behaviour governing acreage allocation by two classes of farmers and also investigates allocation inputs for competing crops). Further discussion of the integrated models incorporating these features are discussed in Chapter 5.

4

Nutrition Planning Models : A Survey

The nutrition system may be divided into two broad sub-systems: the consumer sub-system, and the producer sub-system. The application of programming models in nutritional studies is of recent origin. We have numerous applications of programming models in the consumer sub-systems. Most of them are minor variants of classical formulations of the diet problem, with the objective of getting that set of food items that will provide the required nutrients with minimum cost. Thus, they concentrated only on subsistence. Also, the models are at an aggregated regional level or at household level, ignoring the distribution of inter-household and intra-household food items. They mostly have the simplified linear constraint system with a direct linear transformation of foods to nutrients ignoring the nutrient interactions not only among the food items but also interactions of food items with the health status of indivduals. There are no significant attempts reported in literature which integrate the production sub-system consistent with objectives of better nutrition.

It is now well-known that the problem of malnutrition has numerous dimensions and the focus for nutrition planning must be multi-sectoral. We shall not attempt to trace out all the sub-systems involved in nutrition planning but look at the economic sub-systems that relate the purchasing power to the food production and supply, that set of forces which balances the consumer's demand for food with the producer's supply through price operations in the market place and

through variables under State control. Ttaditional policies to influence the food supply and demand (produder credit, extension facilities. cropping pattern, irrigation and commodity pricing policies) and the incomes policies designed to generate employment are also to be examined in detail. But the existing data base of such a detailed process, addressed from nutritional view point is very poor and what we encounter in the literature are studies that look at the consumer system and producer system individually. Integrating them with clear objectives at a macro level is essential for nutrition planning as otherwise the studies would lead to sub-optimal results.

It is widely realised that a systems approach to reduce malnutrition is fruitful because it takes into account many inter-dependent determinants. Model building exercise should accommodate these factors along with nutritional objectives. The obvious tool for such an exercise is mathematical programming and in this part of the report we shall review its applications in nutrition problems, as dealt by various researchers. Subsequently, we shall formulate appropriate models.

Parameters

We have elsewhere described the nutritional composition of a satisfactory diet by listing the quantities of the principal nutritional elements that the diet should contain. Some of the nutrients known to be needed for good nutrition are included in such a list, either because the quantities needed are not well-known or because a diet that is adequate with respect to principal nutrients, is usually adequate with respect to the remainder. The nutritional allowances are usual'y specified as minimum quantities; excesses of many nutrients are not ordinarily harmful unless they are usually large. In some cases, the quantity of a nutrient cannot be specified without knowing the quantity of some other nutrient or nutrients consumed. This problem can be handled either by stating some of the allowances in ratio form or by requir-

ing that a certain allowance be satisfied exactly, so that the quantity in the diet becomes a known constant. These are typically handled in the constraint system in any programming model. Details of the various metabolic physiological interactions depending on the various levels of intake of different nutrients are dicussed in Chapter 2. However, in view of the non-availability of functional relationships between many nutrient inter-relationships and metabolic inter-relations, the possibilities of incorporating these features are limited.

Consumer Sub-system

Various types of consumer models for least cost diet have been formulated in literature and some of them were empirically tested for meaningful solutions. Some of these are discussed later. These formulations differ from one another in terms of accommodating one type of constraints or the other, for instance, some deal with traditional food habits, some with consumer budgets, etc., in addition to minimal requirement of various types of nutrients. These models differ also in terms of the level of aggregation. From the point of view of technical approaches, most of them fall under linear programming approach and a few under non-linear programming approach. Apparently the latter category seems to more realistic. However, very few empirical studies exist pertaining to this approach. In subsequent paragraphs we discuss briefly various formulations highlighting the important features of these.

Panikkar [40] tried to find a dietary pattern that will provide the necessary nutrients at a minimum cost given the food resources and their relative prices. The exercise is attempted with particular reference to Kerala, taking the nutrient allowances for an adult engaged in moderate work as a standard. The solution is obtained by minimising the cost function $\sum_i c_i x_i$ subject to $\sum_i a_{ij} x_j \geq b_i$ and $x_j \geq 0$ with a_{ij} = the

40. Panikkar PGK. Economics of nutrition. *Economic and Political Weekly*, February 1972, pp. 1-21.

number of units of the i^{th} nutrient in 100 gms of the j^{th} food, b_i = the number of units of the i^{th} nutrient required, x_j = the number of units of the j^{th} food to be purchased and c_j = the cost of 100 gms of the j^{th} food. But the solution obtained with the aforesaid constraints lacks variety. The composition is dominated by tapioca and the amount prescribed in the diet exceeds very much the normal level of consumption. One has, therefore, to look for alternative optimum solutions which offer greater palatability. Few alternative solutions are attempted by setting lower limits of consumption for preferred foodgrains like rice, horsegram, etc. The solutions indicate that a diet which provides the sufficient levels of essential nutrients and reasonable palatability is within the reach of the most people in Kera'a. The above exercise owes its origin to Stigler. [41]

Sukhatme [42] estimated the least cost diet and the pattern implied in the agricultural production. It was ensured that no large changes were introduced into the existing dietary pattern of the people. The computed changes should be feasible for implementation [43] and within the economic reach of the people over a reasonable period of time. These modifcations constitute the additional restraints necessary to obtain a realistic solution. With these considerations, additional restraints in the form of lower limits for certain food crops and upper limits for others were made in order to make the solutions realistic from the nutritional, economic, and production points of view. These solutions, along with the existing levels of supplies on a per capita basis for the different food groups are shown in Table 4.1.

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41. Stigler. The cost of subsistence. *Journal of Farm Economics* May 1945.

42. Sukhatme P V. The world's hunger and future need in foods supplies. Journal of Royal Statistical Society (A) 1931, 124, Part 4, No. 463-525.

43. As an example, it is conceivable that the target for animal proteins for the Far East could be met by an increase in the supplies of fish alone, which in this region is the cheapest source of animal proteins.

Table 4. 1 : Realistic Solutions

(grams per day)

Food supplies	Far East				Near East	
		Required				
	Available	Short-term target	Inter-mediate target	Long-term target	Available	Required
Cereals	404	429	384	368	446	401
Starchy roots	156	156	156	156	44	44
Sugar	22	25	29	33	37	44
Pulses and nuts	56	73	82	92	47	47
Veg. and fruits	128	192	256	307	398	398
Meat	24	30	42	60	35	53
Eggs	3	4	6	8	5	10
Fish	27	38	54	74	12	15
Milk	51	73	119	137	214	307
Fats and oils	9	12	15	18	20	25
Total calories	2,070	2,300	2,300	2,400	2,470	2,470
Vegetable proteins (g. per day)	48	55	54	55	62	57
Animal proteins (g. per day)	8	10	15	20	14	20
Overall index of food required	100	120	141	167	100	117

The emphasis was mainly on calories, animal proteins, and total proteins. The last row of the table gives the index of per capita food required based on the price weights, computed from the data on regional producer prices expressed in the form of wheat price relatives.

A point that must be made now is that these studies do not take into account the consumer's income, though the cultural factors, in way of restraints on their preferred food items are being taken care of. The solutions only refer to average levels for the population as a whole. A better source of information on actual food intake is Household Food Consumption Survey. Households are randomly selected and their food consumptions are recorded through oral enquiries or by weighing the food items, for a specified period of time. Florencio and Smith [44] have studied the efficiency of food purchasing among the working class families in Columbia, using the household food consumption data. Efficiency in the purchase of food is used to mean nutritional efficiency—the degree to which the nutrients purchased were obtained in the least costly way. The total food expenditure is divided into nutritional and non-nutritional or cultural components. Nutritional expenditure is defined as the expenditure that would have been required to buy the actual nutrient intake if it had been purchased in the most economical way, with no consideration of palatability or taste preferences other than limiting the foods to those commonly eaten in the area. Non-nutritional expenditure equals the total food expenditure minus the nutritional expenditure component.

Determining the nutritional expenditure require : (a) measuring the nutrient intake for each family; and (b) determining the least costly diet that would provide that intake. Standards to be met are the quantities of each of twelve nutrients consumed by each family. For the B-vitamins, however, allowances are made not as absolute quantities, but as proportions of the calorie intake. With the usual symbols, we have,

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44. Florencio, Smith. Efficiency of food purchasing among working class families in Columbia. *Journal of American Dietary Association* 1969 Vol. 55, pp. 239-45.

Minimise $Z = \sum_{j=1}^{n} p_j x_j \quad (j = 1, 2 \ldots n)$

subject to (1) $x_j \geq 0$

(2) $\sum_{i=1}^{8} a_{ij} x_j \geq b_i$, Total protein, animal protein, fat, calcium, phosphorous, iron, vitamin A, and ascorbic acid.

(3) $a_{gi} x_j - x_{n+1} = 0$ calories

(4) $a_{10\,j} x_j - x_{n+2} = 0$ thiamine

(5) $a_{10j} xj - x_{n+3} = 0$ riboflavin

(6) $a_{12j} xj - x_{n+4} = 0$ Niacin

(7) $x_{n+1} > b_{n+1}$ Calories

(8) $-K_{n+2} x_{n+1} + x_{n+2} \geq 0$ Reference level of thiamine

(9) $k_{n+2} x_{n+1} + x_{n+2} \geq 0$ Reference level of riboflavin .

(10) $-k_{n+4} x_{n+1} + x_{n+4} \geq 0$ Reference level of niacin

The model includes only nutritional restraints. However, limiting the list of foods to common food habits and taste preferences have had an indirect effect on the least cost diets.

Following this, a similar study was made on families in Bicol region in Philippines by Ericta and Florencio[45] since cultural factors play a major role in shaping food habits, the study compared the least cost diets using only nutritional and cultural factors. Because of fluctuation in prices, it is possible that the composition of least cost diets will change

45. Ericta, Florencio . Least cost nutritionally adequate diets for families in Bicol region. Part 1. Composition, cost and effect of price change. *Nutrisyon* 1976, (1).

as price changes. The study compared the effect of prices at two different periods on least cost diets. The mathematical model which used only nutritional constraints is not exactly a pure subsistence model since the commodity list used in the study consisted of foods which were widely accepted in the area and not just any food which was available to the families. To accomplish the cultural objectives, the model used explicit conventional restraints designed to force the diet into a pattern that corresponds more or less to conventional food consumption habits. Since 99 per cent of the samples consumed rice and fish, the model imposed minimum requirements on these foods. With the above restraints explicitly presented for the earlier model, the following changes are made :

(7) $b_2 \leqslant x_{n+1} \leqslant 1.1\ b_1$: defines that the calories provided by the diets must be greater than the requirement but must not exceed 10 per cent of the requirement.

(11) $x_j \quad \geqslant 150$
(12) $x_{j+1} \geqslant 60$
} Cultural constraints

The food items which comprised the least cost diets were predominantly from plant sources: the absence of meat, fruit, and fat, the costly sources of energy was notable. Although 246 families varied in size and composition, there was little variation in the kinds of foods which make up the least cost diets. Hence, for a standard family, to allow for more flexibility in the choice of foods, alternative diets were worked out. Using the least cost diet, as basis, Ericta and Florencio [46] have also computed the marginal cost of nutrients, which is the smallest expenditure that will provide an additional unit of the nutrient, leaving the quantities of other nutrients unaffected. Knowledge of the marginal cost of nutrients will

46. Ericta, Florencio. Least cost nutritionally adequate diets for families in Bicol region: Part II *Nutrisvon* 1976, 1, 2.

enable the nutritionist to identify the expensive and inexpensive nutrients and determine the cost of supplementing the existing deficiencies.

After formulating the dual of the LP model to get the costs of nutrients, Smith [47] has evaluated various diets. Given the objectives of the diet, the relative scarcities of nutrients depend upon the pattern of food availability. Although it may be convenient to express the marginal costs of nutrients in terms of customary physical units, such units can be quite inappropriate for evaluating the relative scarcities of particular nutrients, for the physical unit may have no relation to the quantity needed by the body. An appropriate unit for comparison of marginal costs would be 1 per cent of the nutritional requirements to be met. They give a picture of the relative scarcities and is very useful for the purposes of supplementing when few nutrients are lacking in the diet.

The nutritionist measures the quality of a protein by its chemical score–the ratio between the actual amount of the limiting essential amino acid and the quantity that would be present in the same weight of reference protein(FAO).report[48] However, to formulate eonomical diets, we must look at the diet as a whole not at the scores of individual proteins. Two things must be specified : (1) The proportions in which the essential amino acids (methionine, trytophan, lysine and threonine) are to be combined, and (2) the minimum proportion of essential to non-essential amino acids. If economical diets are to be planned, we must be able to economise on the essential amino acids by allowing the non-essential ones to play their full role in tissue formation.

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47. Smith. *Linear Programming and the Attack on Malnutrition*. Mexico.
48. FAO WHO Ad-hoc Expert Committee Report. *Energy and Protein Requirements*. 1973. WHO Tech. Rep. Ser. No. 522.

The quantitative relationship between the concentration of protein (the protein calories per cent), the quality of the protein and the net protein utilisation is known and this is non-linear. Smith[49] has presented a complete nutritional model with the above non-linear restriction, but of a simple shape. Since the efficiency of protein depends upon the kind of protein it is, protein needs cannot be stated so many grams per day for a person of given age, sex, and body weight. If we fix up the protein quality in advance, we rule out opportunities to economise by consuming a small quantity of higher quality or larger quantity of lower quality. This is essentially taken care of by the non-linear restraint. The complete nutrition model advocated by Smith has been presented in Table 4.2.

Table : 4.2 Complete Nutritional Model

Restraint Number	Restraint	Purpose
(1)	$a_{ij}\, x_j = 2266$ k cal,	Provides a pre-detetmined amount of food energy
(2)	$a_{2j}\, x_j - u - s = O,G$	Provides food protein at least equal to the quantity of fully utiilsable protein in the diet
(3)	$u + s - t = O,G$	Defines the total food protein variable at t as equal to u+s, using (2), $t = a_{2j}\, x_j$

49. Smith. A diet model with protein quality variable. *Management Science* 1974, 2016, pp. 971-80.

Restraint Number		Restraint	Purpose
(4)	(1-7-6t/Co)u	+0.08(1-7,6t/Co)	t-34.4g. Provides the minimum fully utilisable protein required to attain a reference protein level of 34.4 g or more
(5)	$a_{5j}x_j$	–388.7 g	Provides a minimum quantity of calcium
(6)	$a_{6j}x_j$	–13.3 mg	Provides a minimum quantity of iron
(7)	$a_{7j}x_j$	–433. IU	Provides a minimum quantity of vitamin A
(8)	$a_{8j}x_j$	–1.135 mg	Provides a minimum quantity of thiamin
(9)	$a_{9j}x_j$	–1.02 mg	Provides a minimum quantity of riboflavin
(10)	$a_{10j}x_j$	+100n –11.47 mg	Provides a minimum quantity of absorbic acid
(11)	$a_{11j}x_j$	–27.49 mg	Provides a minimum quantity of ascorbic acid
(12)	$a_{12j}x_j$	–0.040000 O G	Provides a minimum ratio of lysine
(13)	$a_{13j}x_j$	–0.034240 O G	Provides the minimum ratio of the sulphur containing amino acid
(14)	$a_{14j}x_j$	–0.017120 O G	Provides the minimum ratio of methionine
(15)	$a_{15j}x_j$	–0.031680 O G	Provides the minimum ratio of methionine

Restraint Number	Restraint		Purpose
(16)	$a_{15j}x_j$	−0.00920 O G	Sets the quantity of trytophan available for use, in fully utilisable protein or for conversion to nicotionamine, equal to the quantity provided by the diet

Z = Net protein utilisation (expressed as percentage)

r = the quantity of reference protein (in gms per person per day)

t = the quantity of actual food protein required (in gms per person per day)

$\frac{Zt}{100} = r$; (1)

u = the quantity of fully utilisable protein (in gms per person/day)

s = the quantity of food protein in the diet that is not used in constructing fully utilisable protein

c = the total number of metabolisable calories in the diet (in k calories per person per day)

$100\ \frac{u}{t}$ the protein score and $4\ (100)\frac{\frac{3}{4}}{c}$ the protein calories percent. Then

$Z = (100\ \frac{u}{t} + 8)\ 1 - .019\ (4(100)\ t/c)$: Net protein utilisation (2)

Eliminating Z we have

$u\ (1-7.6t/c) + O.\ 08t\ (1-7.6\ t/c) = r$ – (3), which sets the minimum quantity of u needed to provide the required amount of reference protein for any level of t which may be provided in the diet.

Criticising least cost diet models, Prynor (in a private communication) says : "The model assumes that the household has a well defined and always applicable rule for purchasing and eating food and that rule is one which relates nutrients to costs. In reality, man uses a much more round about way for assuming that he gets an adequate supply of nutrients". He further argues that the food consumption is influenced by culturally derived factors and defining what is called a 'preferred diet; not in terms nutrients, but in terms of quantities of various commonly eaten foods, he has suggested the following model :

$$\text{Maximise} \quad \sum_i \left| X_i - b_i \right| \quad \text{subject to}$$

$$\sum_i p_i x_i \leqslant \text{budget for food}, \; x_i \leqslant 0$$

where b_i : preferred diet (quantities of commodities)
P_i : prices

But here again, selecting the ideal diet poses problems. Also, the model is less open in terms of choice of the food items and the possibility of changing the pattern through nutrition education programmes is not seriously considered.

Lancaster, [50] and Prato [51] considered least cost solutions incorporating consumer utility also; multiple attributes of commodities in general, tastes and preferences in particular are also attempted to be incorporated. The data requirements and utility specifications render these formulations non-operational. Some of the details of these models are reported in Chapter 3.

Palatability is an important aspect of diet specification. Stigler's attempt to arrive at a least cost diet without wheat

50. Lancaster. *Consumer Demand. A New Approach*. New York, Columbia University Press.

51. Prato. A proposal for reducing nutrient deficiencies with economical diets. *American Journal of Agricultural Economics* 1974 pp. 15-21.

flour, cabbage, spinach etc, the important food items, appears to be practically irrelevant. Smith [52] has constructed the diet model with palatable food items but the results are based on many subjective assumptions. The important parameters set of the models, the set of relative prices very much depends on the availability of different food groups — a fact which is not built into the above models. While computing the quantities of food groups, we have to ensure that no large changes are introduced into the existing dietary pattern of the people, at any rate not in the immediate future and should be within economic reach of the people. A starting point must, therefore, be the existing levels of supplies for different food groups, modified where necessary, so as to satisfy these basic criteria. These modifications in fact constitute the additional restraints necessary to obtain a realistic solution.

Production Sub-System

Supply of nutrients is a three-stage process: (1) Production (both agricultural and non agricultural), (2) Processing and (3) Distribution. In this sub-section we shall be briefly touching upon the production system only. Considerable literature exists on agricultural planning under least cost objective or other variant of this objective. Some of them notably the ASCI Report on All India Grain Storage and Distribution Study (1976), integrated the demand and supply equality as essential part of the constraint system, need different objectives in planning models for agricultural system. However, integration of demand and supply in terms of equality of nutrients from both the sub-systems has apparently not been attempted in detail in published literature. Towards the end of our survey, we are introducing some of these formulations, the details of which are discussed in the next section. However, one or two studies on production system in the context of nutritional planning deserve mention here and these are elaborated below:

52. Smith. Linear Programming modeles for the determination of palatable human diets, *Journal of Farm Economics* 1959, Vol. XLI No. 2

Since the supply of nutrients in our diets is mainly from cereals and pulses, it becomes essential to look at possible agricultural improvements and the capacity of our agriculture system to produce non-food income, from a given set of resources with each set of agricultural methods, subject to the requirement that the population be equally well nourished. Smith and Hossein[53] have given a method, which, in summary, is as follows : The income produced by agriculture is divided into either food or non-food items, Let the purpose of food production be meeting nutritional needs of the population. Resources not used to meet nutrient needs can produce non food income. An improvement in food production reduces the resources for meeting these nutrients objectives and permits producing more non-food goods. Improvement in non-food production expand non-food output directly. The effects of even improvement whether in food or non-food production, are converted into changes in the output of non-food income. Formally,

$$\text{Max } Z = \sum r_j x_j \text{ where}$$
$$X_j \geq 0$$
$$\sum_j a_{ij} x_j \gtrless b_i$$

Where Z is the net contribution of the agricultural sector to the gross income and r_j the monetary revenue or expense associated with one unit of activity, X_j Each a_{ij} is the technical coefficient associated with the i^{th} activity and the itn restraints. The model is applied to different ecological areas, activities and restraints generally being specific to a given area.

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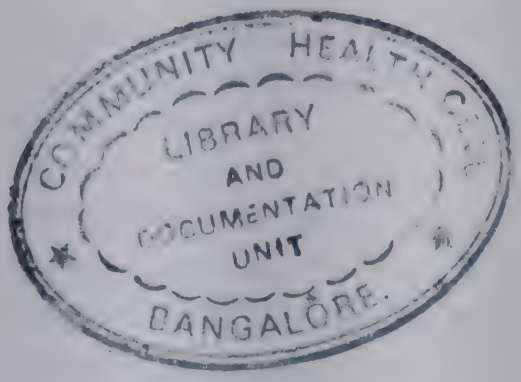
53. Victor E Smith, Hossain Yaghoobi-Rahmatabadi. Agricultural improvements, nutrient needs and the capacity to Produce non-food income. *Food and Nutrition* **1975** (Nigeria) **1 (3)**.

In application, the model selects foods to meet nutrient requirements on the basis of opportunity costs. If several crops can provide the same set of nutrients, those that use resources of relatively little value in the production of non-food income are allocated to food production; when the specified nutrient requirements have been met, the resources remaining are allocated to the production of non-food income. Land is used for food rather than for non-food production only if the value of the non-food income that it can produce is less than the cost of any alternative means of providing the same nutrients. Alternatively, means of obtaining nutrients include buying food from other countries, from other parts of the country or from non-agricultural sectors within the country (for instance, fishing or brewing). Ruetlinger and Selowsky[54] have examined the cost effectiveness of alternative nutrition intervention strategies. The limitations of this approach are briefly discussed in the next chapter.

As we notice from the above survey, a dynamical (multi-period) integrated nutrition model incorporating demand and supply sub–system along with the relevant parameters of public/government intervention is hard to locate in published literature.



54. Ruetlinger S. Selowsky M. Malnutrition and poverty - Magnitude and policy options. *World Bank Staff Occasional Paper* 23,1970.

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Formulation of Integrated Nutrition Models

Since an increase in the income levels of the society is not a sufiicient condition to mitigate the problem of mal-nutrition and under-nutrition even if we have a clear concept of mal-nutrition it is necessary to explore various measures that affect the effective consumption of various nutrients in different age-sex groups of the population with varying levels of income. This would call for a pragmatic approach to intervene in the process of production of nutrients, availability of nutrients at prices within the reach of the affected population, and providing enough incentives including those that will alter the preference pattern for consumers to affect the pattern of consumption of food items, and take steps to ensure greater utilisation of nutritional intake so as to arrive at desired nutritional status for the society. Since the intervention involves certain direct and indirect costs to the government and to the individuals, a dynamic optimal intervention strategy comprising the choice of a set of policy instruments valid for multiple time-periods integrating the aspects of supply of nutrients, and of consumption and absorption of nutrients. Therefore, schemes which are generally taken up from a non-nutritional angle, for instance, protected water supply, could be treated as nutritional intervention programmes as they could effect as much for the improvement in nutritional status by improving the absorption capacity for a given level

of utilisation/ absorption capacity (marginal changes in this level could be possible due to the prevalence of nutrient inter-relationships and hence of changes in assimilation of different types of nutrients).

To accomplish this, we need firstly to have a close understanding of the demand for nutrients from a normative viewpoint, that is, the physiological specifications in terms of requirement of different nutrients by different age-sex occupation groups. To a large extent, this information is available from sources like FAO/WHO studies. However, we noticed that the state of knowledge is insufficient to explain the complex relationships between different levels of intake of one or more of nutrients and the performance indicators of nutritional status of an individual's health. It is well-known that the few months preceding birth and subsequent three to four years form the most critical stage of physical and mentaldevelopment of human beings. However, questions like (i) what is the extent of reversibility of the affects of undernourishment in this critical phase under varying types of intake of nutrients in subsequent years, (ii) what is the impact of genetic characteristics relative to the role of nutritional intake, (iii) what is the relationship between metabolic rate of utilisation of nutrients and the nutritional status in earlier stages of life, do not seem to have unambiguous answers. The logical structure which could provide insight into the directions in which further explorations on issues relating to the questions raised above is indicated as given in the draft report of the study.

It appears that the more pertinent problem is that of relating the nutritional requirements of individual to different important characteristics, such as infantile nutritional status, age, sex, etc, and other important parameters like metabolic characteristics and nutrient inter-relationships in assimilation. For the purpose of models depicting nutrition requirements over periods like months or years for individuals with speci-

fied characteristics, it is, therefore, needed to evolve a model analogous to the one suggested in Chapter 2.

The physiological demand (requirements) specification for nutrients is independent of the socio-economic parameters (other than type of work) and we should design behavioural demand functions or derived demand functions of intake of nutrients by different sections of the society, in terms of the influencing parameters like levels of education, prevailing relative prices of different commodities, income levels, and other attributes of commodities including traditional food habits. Once these relationships of variables affecting the intake are quantitatively assessed, the next task would be to design proper intervention schemes so as to enable the behavioural demand to match with the physiological needs thus reducing the gap between the two as close to zero as possible, given the resources for this purpose.

The nutrient supply can be viewed as a multi—stage process in terms of production of different items, processing, trade, and distribution. The exercise in this case should focus on meeting the aggregate nutrition requirements by designing proper policy intervention schemes affecting the above constitutents of effective supply system.

The broad categories of intervention affecting the nutrition system include (a) types (by variety and quality) of agricultural inputs—quantities and prices; (b) procurement, trade, and pricing operations for agricultural products so as to achieve the desired food production; (c) public distribution and other modes of supplying different varieties of food items and their pricing, that is, steps, including nutrition education programmes, to ensure greater consumption of nutrients; (d) integrated health and environment and other systems, so as to increase the efficiency of utilisation of nutritional intake; (e) information dissemination, including training and skill formation; (f) differential policies of sup-

porting (i) consumption in different age groups, (ii) production activities in various regions by different classes of farmers; (g) regulations on acreage allocations and procurement operations; (h) buffer stock policies; public distribution system (quantity and pricing extensity and intensity of intervention ; and (i) integrated health, nutrition, family welfare, and education programmes ; supplementary foods and feeding programmes.

The intervention strategies should aim at evolving an integrated approach affecting both produce system and consumer system at macro-and micro-levels of each system. The intervention should be so optimally designed to bring about, behaviourally, a reproachment between the desired socio-economic objectives and the existing realisation of the same. The analysis for designing such an inttervention can be best done by examining the decision-making process by different units in their production and consumption behaviour under differing sets of available alternatives and information associted with the decision-making processes, for example, the micro-level utility function governing individual consumption can be treated not only as a function of economic parameters like price of commodities and incomes but as a more general and realistic function, including in its arguments like attributes of commodities, information set indicating the available/utilised information (in formulating the objective function (s)/ utility function). Alternatively, the specification of utility functions should be viewed in conjunction with corresponding sets of information available for consumption decisions. Now the issues are :

(a) How to bring about the treatment of different modes of intervention into the formal analysis?

(b) What is the relevance of cost effectiveness? Approach or cost-benefit analysis in the integrated approach to betterment of nutritional status? What is the relevance of optimisation approach for this purpose ?

These are inter-related issues. If we examine carefully the design of intervention programmes, many types of which are stated earlier, the approaches become clear. In order to arrive at a meaningful design, we need a comprehensive definition of nutrition problems and objectives thereof.

It is desirable to relate the nutrition intervention programmes with the desired health status of the population, than simply the desired nutritional status, since health status has greater relevance for the societal status and welfare. It is well-known that there is a type of cyclical relationship to some extent between the nutritional status of an individual in a period and the general health status of the individual in the same or subsequent period. This is particularly true of sections of the society which are under-nourished or malnourished, which constitutes the target population whose nutritional status is sought to be improved. The important link between the two seems to be factors relating to disease resistance and absorption of nutrients in the body.

For the present, let us confine our attention to the central issue of nutritional status and relate it to influencing parameters which include partly the health status. Nutritional status at any time t of an individual is mainly a function of :

X_1 : Genetic/heriditary and congenital features, including initial (birth stage) health status, anatomical and developmental features.

X_2 : Nutritional needs, as dictated by the physiological features, type of work, intestinal atony and atrophy, bacterial changes and absorption.

X_3 : Intake of food (quantity, type, timing, quality, and biochemical aspects).

There is considerable evidence[55] that heridity or

55. Alan Berg. *The Nutrition Factor*. Brookings, 1976.

general features set certain limits on human growth, but nutrition may be regarded as the main factor that enables the body to achieve these limits. Some of the biological experiments [56] using a comparative frame have shown that the failure of the infants to show a satisfactory growth, in spite of provisions of protein and calorie rich nutritious supplement, may be attributed to maternal nutritional deficiency during pregnancy.

Infections and other diseases affect human growth through nutrition. It is well-known that there is very close relationship between malnutrition and prevalence of infectious disease. Studies made in several countries suggest a cyclical relationship between malnutrition and infections. This shows that immunisation programmes may result in considerable improvement in the nutritional status and, therefore, could be treated as an intervention programme for nutritional purposes.

However, it is obvious that each of these parameters X_1, X_2, and X_3 are themselves functions of several other parameters and deserve careful attention. For example, X_2 which is composed of several parameters, has metabolic absorption which itself is a function of the following :

Nutritional composition of food

Level of activity

Infection and parasites presence

Metabolic effects and nitrogen loss

Iron content

X_3 is a function of economic parameters like income, relative prices of different commodities, apart from factors like food habits, traditions, anorexia, etc. Thus, it is clear

56. Venkatachalam et al. Effect of nutritional supplementation during early infancy on growth of infants. *The Journal of Tropical Pediatrics* 1967, 13 (2), 70-76.

that the nutritional status N is a function of several parameters and can be expressed in terms of interventions, in the following implicit function form :

$$N^t \equiv f\ (Y_1,\ ,Y_2,^t\ Y_3,\ Y'_4 Y_5,'\ Y_6,'\ Y'_7 A)$$

Where Y_1 depicts initial conditions at birth, (including genetal inheritance, state of health, etc) i.e. at t = O.

Y_2 state of health at current time period t

Y_3 level of nutrition and general education

Y_4 disease prevalence index (including infectious, etc)

Y_5 intake of food items and nutritional composition

Y_6 environmental factors contributing to differential nutrient absorption

Y_7 income level

A dummy parameter representing residual factors.

It should be noted that the above formulation, when taken up for empirical estimation, should be more specific depending upon the specific target group of population for which the intervention is aimed. Also, we shall be concerned with the status group of persons, whether constituted by multiple age- groups or a single age-group(like children) and not necessarily with an individual. The study of a typical member of the target group could, however, provide insight into the working of the system. Clearly, the quantification of different parameters Yi is not easy, Similarly, identification of the function using all the factors is not useful both for statistical estimation purposes and for designing practical intervention schemes (which are generally treated in separate activities).

This calls for approximating the above scheme of identification. One of the important factors affecting the nutritional status is the factor relating to immunity of target population from infections diseases of different kinds. This factor it self depends upon: (a) application of preventive medicines-me-

dical immunisation, and(b)nutritional and general health status of the persons. "The overlap of the geographical distribution of malnutrition and infections diseases has long been observed. The possibility of an association between infection and malnutrition has received a good deal of attention ... studies made in several countries have suggested a cyclic relationship between malnutrition and infections .....immunisation programmes in areas where malnutrition is common may also result in some improvement of the nutrirional status of the community". [57]

Since body resistance is related, among others, to environment which includes sources of infection–air, water, and hygiene–it is necessary to examine the relative impact of intervention in one or more forms affecting the environment. This is also needed to ensure greater utilisation of nutrient intake. Thus, schemes like protected water supply, sanitation programmes, etc, deserve attention. Hence, the question arises as to which programme or combination of programmes is most effective to improve the nutritional status. In order to know the answers, one has to attempt establishing the empirical relationship between the nutrition status and different combinations (by type and intensity) of intervention programmes. That is, we may require different functional relationships (may be linear or non-linear) between N^t and different combinations of Yis. The differential impacts of Yis and the statistical significance of the same can be depicted by proper estimation of relations. However, for policy purposes, it is necessary to make choice of intervention programmes under the cost-effective criterion: find the schemes which cost the least to achieve a desired target of nutritional status. This question is not the same as the one which was attempted using the cost-effectiveness criterion by the IBRD Occasional Paper (No. 23) *Malnutrition and Poverty = Magnitude*

57. Awdeh Z1. Nutrition, infections and immunity *In* MC Lareu DS. Ed. *Nutrition in the Community* New York, John Wiley, 1976, pp. 17- 21.

and Policy Options by S Ruetlinger and M Selowsky (1976) and several other studies known hitherto. In these studies, the issue was to find the schemes which are cost-effective in terms of additional intake of desired nutrients and not in terms of the more pertinent indicator–nutritional status which is a function of not only of intake but also of absorption, etc.

Thus, in an integrated approach we are required to take the total set of instruments for achieving nutritional goals. It is quite likely that the fiscal and administrative costs involved using this approach are significantly less compared to nutrition intervention programmes attempted only by direct intervention in demand and supply sub-systems. Since a single comprehensive optimisation model under the objective of cost minimisation and using the functional relationships, targets of nutritional intake and status, budgetary constraints and other constraints relating to traditional factors, policy intervention limitations, etc, is a formidable task for computational purposes, it is meaningful to approximate the model by decomposing it, without losing the integration aspects, into smaller sub-models which can be solved separately and then integrated in a consistent manner.

For this purpose, it is advisable to isolate the intervention programmes, which, in a sense, are indivisible with respect to Individuals like nutrition education, sanitation and preventive medicines, natural betterment of disease resistance by improving quality of water, etc. The programme can be designed by using the cost-effectiveness analysis (using project appraisal and ranking techniques. Subsequently, consistent with the proposed environment regarding the above factors, that is, treating those as given), optimal intervention by quantity and type of different other variables, which affect largely the nutritional intake, can be derived by using mathematical programming methods.

It is possible to formulate a comprehensive model to arrive at optimal nutrition intervention policies. This could be accomplished in the following manner: Formulate an input-output frame in respect of each possible intervention sub-system, for instance, school feeding, processing of foods, etc. When inputs are in terms of economic parameters like prices of commodities and other inputs (like labour), and outputs are (linear) functions of the resultant nutrient gain (in respect of different nutrients) in terms of, say, some of the anthropometric features. Once this frame is arrived at, optimisation models, incorporating the least cost objective or the maximisation of parameters of nutrition status subject to the input-output relations and other relevant constraints, can be formulated. However, it will have to obtain the input-output relations using the existing knowledge. Hence, the need for formulating models which can reasonably approximate the above type of general model.

The subsequent section deals with these details. An important aspect which deserves attention, given that the early age-group and a reasonable period preceding the stage of birth is considered vulnerable, is the relevance of identifying the structural relations governing the nutritional intake and the status of the child in terms of factors affecting the feeding programmes of the child at the household level. These could be in terms of education level of mother, socio-cultural factors, incomes, and prices. If the target group is simply the above vulnerable age-group, the functional relationships governing the nutritional status of a typical member of the target group should be appropriately modified. Here we attempt to formulate the integrated nutrition intervention models covering the consumer over the production sub-system using quantity and price variables.

A survey of nutritional models indicate that it is hard to find the integrated nutritional models incorporating dema nd for and supply of, nutrients using the relevant policy para-

meters, particularly in the context of public systems involving governmental intervention operations. Most of the literature is devoted to consumer lavel least-cost diet optimising solutions subject to various types of minimal requirements specifications for different nutrients. Variants of this exercise applicable to different socio-economic groups or age, sex groups in different geographic parts have been worked out empirically, some of which are reported in literature. Very few of the works concerned production systems, but again in an isolated frame, either ignoring the hydro-geological conditions applicable to the area under consideration or ignoring the consumer needs and other constraints. Wherever some integration is attempted, it is at best done by incorporating some numerical specifications obtained exogenously and which are binding either on demand or on supply. Obviously, this is a weakly integrated formulation, and therefore, we attempt in the subsequent sections relatively more useful formulations.

We have discussed separately the possible intervention programmes in demand and supply systems in the light of which we proceed to formulate the integrated planning models. In the formulation given below, the main objective is the minimisation of costs of intervention programmes over a planning period T years. The constraints may be those pertaining to minimum nutritional requirements of various types, traditional consumption habits, and also nutritional goals for various sections of the population. The policy instruments may be price subsidies (or relative prices) in the consumer sub-system and in the producer sub-system,taxation/prices of inputs, etc. The formulation turns out to be either a linear programming or non-linear programming problem depending upon the assumed behaviour regarding the metabolic interaction of various types of nutrients, and specification of functional forms of demand and supply.

Ideally, any planning system should have in the public context a social welfare objective to be maximised over a relevant period of planning. However, since the exact specification of such an objective in functional form is extremely difficult, we resort to an explicit specification of one or more of the surrogate objective functions which are deemed to be close to the social welfare function. Some of these specifications could include consumer-surplus, producer-surplus and costs of governmental intervention at varying intensities in different time periods as arguments in the objective function. Again representation of consumer-surplus and producer-surplus can be done in a variety of methods depending upon the exact nature of the problem, these can be specified close to the reality. For our purpose, we shall take up the objective of cost minimisation or the minimisation of nutrition gap (subject to budgetary constraint).

Now, we turn to the type of features we would like to impose in the formulation. The first system pertains to accommodating some of the important traditional consumption factors so as to ensure that the solution prescribed by the model is not far away from the existing system. The minimal quantities to be consumed in case of some of the essential items for various age, sex, occupation groups are prescribed in this part of the constraint system. The second part of the structure ensures that the effective consumption (affected by various intervention strategies) meets the physiologically required nutritional intake considering age. sex, and occupation (in case of some nutrients, prescription of maximum consumption limits may also be necessary). The third part of the constraint system ensures that the effective supply of nutrients (considering both production and imports) meets the effective demand for nutrients. Various natural constraints like the non-negativity of quantities involved will be operative.

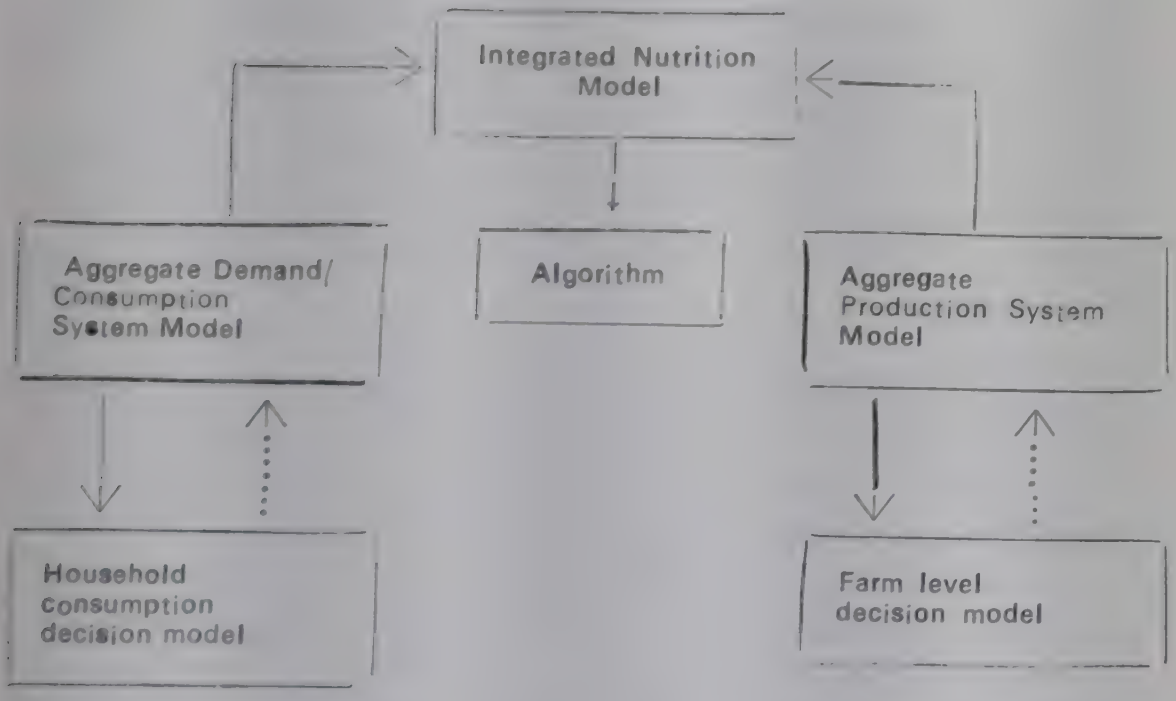
Demand function may be linear or non-linear in the arguments, income, prices of commodities, substitute commodities price, issue price and dummy variable representing

cultural, social, and other factors. Production function may be expressed in terms of commodity price, price of the substitute commodity on the production front, support price if any, procurement price, input prices and quantity of input provided and a dummy variable representing institutional parameters like size of land holding, etc. It may be possible that some of the administrative and legal reforms/ actions turn out to be as effective as the intervention strategies via prices, etc, in affecting, particularly the production system so as to satisfy certain requisitioned properties. Naturally, various alternative systems of marketing, storage, transportation, and public distribution have different effectiveness, in both production and consumer system and merits and demerits have to be examined separately. For example, when various alternative schemes of trading programmes are possible to affect the 0-5 age group children we have to examine them separately through organisational system and also socio-economic effectiveness. Information/ assumptions regarding the allocative behaviour at the household level for any increase in real income via subsidiary programmes in the consumer sub-system intra family distribution is needed to formulate a household decision problem. Similarly, the role of nutritional education, preventive medicines and socio-cultural reforms cannot be ignored and need a separate investigation.

As one would notice, the problem is very complex for mathematical modelling and computation. Broadly, though a single monolithic formulation may be possible, it poses significant computational difficulties. Therefore, we prefer to arrive at an integrated formulation via various inter-connected sub-models. The following bloc diagram indicates the comprehensive system. Various institutional factors like land reforms, alternate systems of feeding programmes for vulnerable age groups, and marketing systems, etc. need to be examined carefully; some of these may be brought into the formal models later. Similarly, the level of disaggre-

gation. both in the consumer system (in terms of age/sex/ occupation, etc) and producer system (in terms of classes of farmers, regional democration, etc) needs to be examined and incorporated in formal models.

Integrated Model



Towards Integrated Models

One of the simplest formulations in nutrition planning could be made at the household level where optimal consumption decisions could take place. But for the society/region as a whole, an integrated comprehensive formulation is needed to ensure certain optimising objectives and also meet the demand by ensuring appropriate supply. A relatively simple approach for this could be to formulate the objective as minimisation of nutritional gap by proper choice of policy instruments affecting the consumer system subject to supply exceeding the demand where supply is exogeneously determind. Since this formulation does not possess the essential

behaviour features of both demand and supply systems, we should look for improved formulations. These are discussed in the subsequent pages.

From the flow chart, it is clear that an integrated model should accommodate the decision models at each of the four units, household, farm level, aggregate demand system, and aggregate production system. Also, the interactions — feedback — need to be explicitly recognised. We proceed to formulate accordingly the relevant models. Table 5.3 gives an illustrative list of various types of parameters for each of the sub-system. We shall confine to a slightly smaller set of these parameters in the formal models for reasons of simplicity and data limitations.

In the first stage, household decision problem is one where the objective is to obtain the least cost diet solution (and possibly budget constraint). This gives a set of quantities q^* for a given set of prices of commodities. In the constraint specifications regarding nutritional requirements, the non-linear relationships in interaction at different levels of different nutrients should also be consi ered for greater relism. But this poses, even if these relations are quantitatively established (so far, welldefind relations seem to exist for protein-calorie interaction only), sinificant computational difficulties. At this stage, we may ignore this aspect. In the case of certain nutrients, it is also desirable to impose a maximum limit on physiological relevance as part of the constraint system. Institutional factors like alternate supplementary feeding programmes can be brought into the formal model when we consider the consumer system in terms of various age-groups. But this requires a knowledge of behaviour about the intr a-family distr bution of food under alternate modes of feeding programmes and with respect to changes in real income. Establishing quantitative relations is separa'e study. The role of the other institutional factors like nutrition education or health education, rural health schemes, etc, and their

Table 5.3 : Various Types of Parameters

Decision level	Choice variables	Relevant dependent variables & exogenous parameters	Essential constraints	Primary objective (s)
Household consumption	Quantities of commodities to be consumed	Prices of commodities income & institutional factors	Preferences budget	Cost minimisation utility maximisation
Farm level production	Agricultural inputs allocation, acreage allocation	Credit facility, prices of inputs & outputs, agrarion reforms acreage allocation restrictions	Budget, traditional factors	Profit maximisation
Aggregate demand	Issue price, types and quantities at subsidised prices, nutrition education, environment factors	Demand, quantity, issue prices, income, substitute prices, institutional factors	Preferences, physiological nutrition requirements	Minimisation of cost, of public intervention
Aggregate production/ supply	Prices of inputs, imports, new varieties, of food commodities, acreage allocation regulation	Quantities of inputs used, substitute prices, institutional parameteis	Satisfy demand	-do-

impact need to be examined separately. In stages two-the aggregate demand-the objective of the public intervention scheme is to arrive at a least cost interventionprogramme in terms of subsidies accruing to various commodities so as to influence the behavioural demand (demand relations separately estimated) in such a way that it exceeds q° scaled by the population factor derived in stage one. In this framework, by enlarging the list of commdities to include fortified foods (even if they are marginal alterations of food items considered in the original list) and incorporating the corresponding cost (in shadow prices, not market prices) element in the objective function, one can arrive at the relevance and also magnitude of fortified food items in the intervention schemes. The optimal prices thus obtained, and also the other exogenous prices, will be plugged in the model at this stage and a solution obtained. This iteration continues until the solution stabilises.

From the stable solution thus obtained, demand $\bar{d}$ for various commodities is computed. In stage 3, a model is formulated for farm level decision with the profit maximising objective (this applies probably to only one segment of farmers; to deal with others, different specifications can be made) with a budget constraint, to arrive at optimal agricultural input allocation schemes. The budget constraint can accommodate credit availability factor. In cases where the institutional credit is linked with production of specified commodities, it influences the acreage allocation of the farmer. The proposed model of stage 3, the input allocation along with other constraints, including possibly regulatory stipulations on acreage under various crops determines the acreage allocation. Using these quantities, in stage 4, in the aggregate supply system, the public intervention with reference to pricing of inputs with the objective of minimising the cost of intervention schemes so as to satisfy the demand $\bar{d}$, is derived. This leads to optimal pricing which is used in stage 3 again to iterate until the solution stabilises. From this we obtain

supply under intervention. Supply of nutrients is determined by (i) net production, (ii) processing technology, and (iii) import/exports. In order to influence processing schemes in a desired fashion (like modernising mills, public intervention would result in costs which can be adjoined with the original objective function (in stage 4). This would require quantitative relations on gains in nutrient availability for alternate processing technologies. Imports exports can be exogenously considered. Alternatives in this regard can be ranked after examining the corresponding cost implications in terms of (i) cost of import/export, (ii) cost of intervention in production system given the specific import/export policy.

The illustrative models given below for each of the four stages of the system are formulated with a minimal set of economic intervention instruments. For realistic purposes, straight generalisation to cover more policy instruments at each of the stages can be made. The typical programming models and susequent computational algorithms remain the same. However, additional constraints and parameters governing the realistic system need to be incorporated in order to arrive at workable solutions.

Notation

n = number of commodities
m = number of nutrients
l = number of agricultural inputs
p' = $(\tilde{p}_1' \ldots\ldots\ldots\ldots\ldots, p_n)$ open market pricevect or for q
$\bar{p}'$ = $(\tilde{p}'_1 \ldots\ldots\ldots\ldots\ldots, \bar{p}_n)$ controlled price vector for q' applicable for certain food items (in these cases $\bar{p}_l \leq p_i$) for a section of the population
T = number of time periods
Y_t = aggregate income level
p^s = substitute commodity price in the production system
p_1 = open market price of input
$\bar{p}_1$ = subsidised price of input

p_p = procurement price

p^d = substitute commodity price in the demand system

q' = $(q_1' \ldots\ldots\ldots\ldots\ldots q_n,)$ quantity vector of food items

$\bar{q}'$ = $(\bar{q}_1 \ldots\ldots\ldots\ldots, \bar{q}_n)$ quantities distributed for public distribution excluding import component

$\hat{q}$ = minimum consumption requirements suggested by traditional food habits

q_p = quantity to be procured

$\overset{s}{q}$ = import quantity

q_I = quantities of input

$\bar{r}$ = vector of physiological nutritional requirements

t = time

Γ = transformation matrix (m x n matrix)

$\tilde{p_t}$ = import cost per unit commodity

B = budget

N = population size

A_1 = matrix of coefficients in the behavioural demand relations

A_2 = matrix of productivity coefficients

A_3 = matrix of coefficients in supply relations.

Integrated Model (Four Stages)

In stage 1, the consumer minimises (in the normative sense) the cost of diet subject to meeting physiologically prescribed nutrition requirements. In order to handle the general case, we assume that, of the n commodities, 1 to k ($1 \leqslant k \leqslant n$) are not subjected to any subsidies/government control and that the remaining are available at regulated price.

Stage 1 : Least cost diet to consumer (minimisation of cost with respect to q_i)

$$\text{Min} \sum_{t=1}^{T} \left\{ \sum_{t=1}^{k} p_{it}\ q_{it} \right\}$$

$$\text{Subject to } [\ \Gamma\ ] \begin{bmatrix} q \\ \bar{q} \end{bmatrix} \geq \bar{r}$$

$$\begin{bmatrix} \text{matrix of nutritive value of different commodities (1 to n)} \end{bmatrix} \quad \begin{bmatrix} \text{quantum of different commodities (1 to n)} \end{bmatrix} \geq \begin{bmatrix} \text{nutrient requirements} \end{bmatrix}$$

$$q \geq o$$

$$\bar{q} \geq o$$

Solution : $[q^o]$

Stage 2: Minimum cost of interventions in consumer subsystem (with respect to regulated price $\bar{p}$)

$$\text{Min} \sum_{t=1}^{T} \left(\bar{p}_t,\ \bar{q}_c \right)$$

$$\text{S. t. } [A_1] \begin{vmatrix} \bar{p} \\ p \\ p_d \\ y \end{vmatrix} \geq [\ q^o]$$

$$\begin{pmatrix} \text{matrix of coefficients in the behavioural demand relations} \end{pmatrix} \quad \begin{pmatrix} \text{vector of prices and income} \end{pmatrix} \geq \begin{pmatrix} \text{total commodity requirements of the society} \end{pmatrix}$$

$$\begin{vmatrix} \bar{p} \\ p^d \\ p \\ y \end{vmatrix} \geq 0$$

Stage 1 will be repeated with p^0 values obtained in Stage 2 and then iterated. Once solution converges, compute $\bar{d}$ (demand for different commodities) using p^0 and y^0 values in the final iteration.

Stage 3 : Farm level decision :

Maximum profit to the farmer. This objective can be replaced by production maximisation (which may apply to a larger class of farmers ; IIMA study could give feedback on this).

$$\text{Max} \sum_{t=1}^{T} \left\{ \langle p_t, q_t \rangle - \langle p_{I_t}, q_{I_t} \rangle \right\}$$

with respect to input quantities q_{I_t}

$$[A_2]\,[q_1] \leq [B]$$

[matrix of productivity coefficients] [vector of inputs] $\leq$ [Budget]

$$[q_I] \geq 0$$

Solution : $[q_I^0]$

Stage 4 : Minimise cost of interventions in production system (with respect to p_I)

$$\text{Min} \sum_{t=1}^{T} \left\{ p_{I_t}, q_{I_t} \right\}$$

$$\text{S. t. } [A_3] \begin{bmatrix} p \\ p^s \\ p_I \end{bmatrix} \geq [d]$$

$$\left[\begin{array}{c}\text{matrix of coefficients}\\ \text{in supply relations}\end{array}\right]\left[\begin{array}{c}\text{vector of}\\ \text{prices}\end{array}\right] \geq \left[\begin{array}{c}\text{total demand}\\ \text{for commodi-}\\ \text{ties}\end{array}\right]$$

$$\begin{bmatrix} p \\ p^s \\ p_I \end{bmatrix} \geq 0$$

Solution : $\begin{pmatrix} o \\ p_I \end{pmatrix}$

Repeat stage 3 with $\begin{pmatrix} o \\ p_I \end{pmatrix}$ values of stage 4 and iterate until the solution is stabilised. This solution can be used to compute the supply $\bar{s}$ of different commodities using p^o of stage of 4. Obviously, there are theoretical possibilities of improving on this four-stage model. However, even with this set-up, computational tasks are significant. We propose to reduce to a two or three stage formulation, allowing the possibility of treating the others separately. Trial results are given in Annexure D.

Integrated Nutritional Planning models : An Application of Linear Vector Optimisation

The planning for nutritional intervention in a society can be based on several considerations. Generally, we can either prescribe an optimal intervention strategy given a budgetary constraint by the public authority or minimise the cost of intervention keeping certain minimal nutritional intake requirements as constraints. Quite a number of studies in theory and in practical systems are available in literature about the latter approach, using a variety of techniques, mostly variants of linear programming. The purpose of the present note is to explore the first approach. In this, the nutritional gap minimisation is the main objective given a budgetary and other relevant constraints. Though in simple terms this is a known type of objective, functional/mathematical specifica-

tion of this objective leads us to an optimisation problem with non-comparable simultaneous multiple objective functions. This is particularly true whenever the number of nutrients in respect of which the deficiencies exist and gap to be minimised is greater than one. If there is a way of converting one type of nutrient into another, there would be a possibility of treating the composite of multiple objectives as a single objective (scalar valued) and the problems takes a standard linear programming format.

The objective is formulated as minimisation of nutritional gap with respect to important nutrients, wherever gaps exist and the cost of operations acts as a budgetary constraint with a prescribed limit in the constraint system. However, if the nutritional deficiencies exist in the case of more than one nutrient for various segments of the population, the problem may turn out to be one of multiple criteria optimisation which can pose its own problems in solving.

A two-stage optimisation decision models can also be formulated which can integrate the demand and supply of nutrients. In these, the first minimises the potential and the required intake of nutrients subject to usual constraints, and then the second minimises the gap between realisable demand (obtained from first part) and supply (for those of the commodities which have excess demand) with respect to policy instruments (like procurement price) affecting the production system, and iterate, till a stable solution is obtained. An alternative approach is given later, where the iterative two-stages model can be handled in a less complex fashion if we simplify the formulation of the second stage without necessarily sacrificing the rigour of the model. Considering the requirements of computational facilities including programming, testing, and calibration of one of these models could be done. We may require multi-period linear programming, separable programming/non-linear programming approaches for algorithms.

The following notation has been used in the formulation of the vector optimisation problem :

Notation :

T = no. of time periods/time horizon
n = no. of commodities
m = no. of nutrients
p = $(p_1,.....,p_n)$ open market price vector for 'n' commodities
$\bar{p}$ = $(\bar{p}_1,.....,\bar{p}_n)$ controlled price vector
p^d = substitute commodity open market price in the demand system
p^s = substitute commodity open market price in the production system
P_p = procurement price
p^s_p = procurement price of the substitute commodity
P_I = open market price of input
$\bar{P}_I$ = subsidised price of input
Q = $(Q_1 .....Q^n)$ quantity vector of food items
$\bar{Q}$ = $(\bar{Q}_1.....\bar{Q}_n)$ quanties distributed in public distribution
$\hat{Q}$ = minimum consumption requirements suggested by traditional food habits
Q_I = quantities of input
$\bar{r}$ = vector of physiological nutritional requirements
$\hat{s}$ = traditional/non-negative quantities
t = time
Γ = transformation matrix of nutrients
B = budget (per capita average for subsidy)
Y = income
N = population size
A_1 = matrix of coefficients in the behavioural demand relations
A_2 = matrix of coefficients in the supply relations

Integrated Nutrition Model :

Consumer System : This formulation deals with the problem of nutritional gap minimisation at individual level. D_k (.....) below is a demand function for individual. However, analogous formulation is valid if aggregate level nutritional gap minimisation is attempted by incorporating D_k (.....) as an aggregate demand function.

Stage 1 :

Objective : Minimisation of nutrient deficiency (with reference to issue prices)

$$\text{Min} \left\{ J_i \quad (t) \right| = \left\{ \bar{r}_{i_{mxl}} - \sum_{t=1}^{T} [\Gamma]_{mxn} \times \right.$$

$$\left. [D_k \ (p_t \ , \ p_t^d, \bar{p}_t \ , \ \bar{p}_t^d, \ y \ )]_{nxl} \right\}$$

$$i : 1, 2, \ldots m$$

$$k : 1, 2, \ldots n$$

S. t. (i) $[A_1]$ $\begin{vmatrix} p_t \\ p_t^d \\ p_t \\ \bar{p}_t^d \\ y \end{vmatrix} \geq [\hat{Q}]_{nx1}$

(ii) $\sum (p_{pt} - \bar{p}_t) \ \bar{Q} \leq B$

In this model, we are treating p_t , p_t^d , p_{pt} and y as exogenous variables. So the part one of the constraint system reduces to :

$$[A'_t] \begin{pmatrix} \bar{p}_t \\ -d \\ p_t \end{pmatrix} \geq \hat{Q}'$$

Where A'_1 and $\hat{Q}'$ are matrics obtained after adjusting and the resultant system is

$$a_{31}\bar{p}_{1t} + a_{41}\overset{-d}{p}_{1t} \geq Q_1 - a_{01} - a_{11}p_{1t} + a_{21}\overset{d}{p}_{1t} - a_{51}y$$

$$\text{— — — — — — — — —}$$

$$\text{— — — — — — — — —}$$

$$a_{3n}\bar{p}_{nt} + a_{4n}\overset{-d}{p}_{nt} \geq Q_n - a_{on} - a_{1n}p_{nt} + a_{2n}\overset{d}{p}_{nt} - a_{5n}y$$

As mentioned earlier, the objective functions are not comparable on any given scale of units. As the number of objectives is greater than unity, the space of vectors generated out of realisable values of Ji's is one forming a sub-space of a partially ordered n–dimensional vector space. In view of these features, it is erroneous to think (as one would be tempted normally by drawing an analogy from a scalar objective linear optimisation problem) that it suffices to simply optimise the first part of each of ji's, i. e., the D_i (.....)s as the substractive terms in an exogenously prescribed constant.

Ideally, we should have taken minimisation of squared deviations of realisable and normative values of each of nutrients as objective (with usual constraints). In a multi-period framework with side inequality, this may turn out to be a non–linear vector optimisation problem bristling with several programming and computational difficulties. Hence, the need for a simplified formulation. An alternative exists where the objective could be minimisation of the absolute/ modulus of the deviations and convert this function into linear one as suggested below.

w. r. t. $J_i = \text{Min } g_i$

$i : 1, 2, \ldots\ldots m$

1. $g_i \geqslant \left[\bar{r}_i - r_i\right]$ i. e. $g_i \geqslant \left[\bar{r}_i - \bar{D}_k (\ldots)\right]$

2. $\left[\hat{r}_i - \underline{r}_i\right] \leq g_i$ i. e. $\left[\bar{D}_k (\ldots)\ \underline{r}_i\right] \leq g_i$

3. $\bar{D}_k (\ldots) \geqslant Q$ $k : 1, 2, \ldots\ldots\ldots n$

Where g_i 's are the nutrient gaps that are to be minimised with reference to deficient nutrient $i = \bar{r}_i$ and $\underline{r}_i$ are the prescribed upper and lower limits of nutrient intake. Here we are considering interval of nutrient intakes and one has to consider the necessary relations between the number of instruments and objectives, etc, while solving the problem using the appropriate algorithms. Algorithms like interactive multiple criteria linear programming may have to be explored. Depending on the properties of the algorithms these could be examined.

Stage 2 :

Minimisation of gap between Demand and Supply (with respect to input and procurement prices assuming demand is greater than supply),

$$\text{Min } J_k = \sum_{t=1}^{T} \left[\bar{D}_k - \left\{ S_k (p_t, p_t^s, p_{pt}, p_{pt}^s, p_{lt}) \right\}\right]$$

$k : 1, 2, \ldots\ldots\ldots n$

$$\text{S. t. } [A_2] \begin{pmatrix} p_t \\ p_t^s \\ p_{pt} \\ p_{pt}^s \\ \bar{p}_{It} \end{pmatrix} \geq g \underset{nx1}{[\hat{S}]}$$

$g\hat{S}$ in this constraint system is rather arbitrary and can be specified meaningfully only if the public authority has specific targets in respect of some commodities; even in such cases the optimisation of the objective function alone may be capable of automatically satisfying this requirement. We should note that this problem pertains to only those of the commodities where the previous stage solution prescribed values which exceed the normal production. When $g\hat{S}$ is not well defined, it is safe to take it as O. It is also possible to do away with the formulation of stage 2 model and substitute with less complex formulation where the objective function could be a scalar function, viz. minimisation of the cost of intervention in the production system subject to constraints ensuring that the resultant production matches the demand for various commodities generated from the model in Stage 1. Here, the exogenous variables are $p\hat{t}$ and $p_t^{\dot{s}}$ and so the new constraint system is

$$[A_2'] \begin{vmatrix} p_{pt} \\ p_{pt}^s \\ \bar{p}_{It} \end{vmatrix} \geq \left[\hat{S}' \right]$$

And a typical equation in the resultant constraint system is given below :

$$b_{3i}\ p_{pit} + b_{4i}\ p^{s}_{pit} + b_{5i}\ p_{1it} \geq \hat{S} - b_{oi} - b_{1i}\ p_{1t} + b_{2i}\ p^{s}_{it}$$

$$i : 1, 2, \ldots\ldots\ldots\ldots, n$$

In stage 1 of the above problem, the objective function can be modified by introducing $\bar{r}_i$ (t), a time dependent function, if the public authority plans to bridge nutrient gap in a phased manner. $\bar{r}_i$, nutrient requirement vector can also be viewed as a vector of intervals of nutrient intake. Different sets of policy interventions can be generated by altering the budgetary resources.

Example : Consider a two-commodity, two-nutrient case. Let rice and wheat be the commodities and let calories (energy) and proteins be the nutrients under consideration.

(N. B. : Stage 1 deals with optimisation at the micro level)

$$\text{Stage 1 : Min. } (J_i) = \sum_{t=1}^{T} \left\{ \underset{2 \times 2}{[\Gamma]}_{x} \begin{bmatrix} D_1 (p_{1t}, \bar{p}_{1t}, p^{d}_{1t}, \bar{p}^{d}_{1t}, y) \\ D_2 (p_{2t}, \bar{p}_{2t}, p^{d}_{2t}, \bar{p}^{d}_{2t}, y) \end{bmatrix}_{2 \times 1} + \begin{bmatrix} \bar{r}_1 \\ \bar{r}_2 \end{bmatrix}_{2 \times 1} \right\}$$

(with respect to issue prices)

subject to

$$\text{(i)}\quad a_{01} + a_{11}\ p_{1t} + a_{21}\ p^{d}_{1t} + a_{31}\ \bar{p}_{1t} + a_{41}\ \bar{p}^{d}_{1t} + a_{51}\ Y \geq Q1$$

$$a_{02} + a_{12}\ p_{2t} + a_{22}\ p^{d}_{2t} + a_{32}\ \bar{p}_{2t} + a_{42}\ \bar{p}^{d}_{2t} + a_{5}\ 2\ Y \geq Q2$$

(ii) $\left(p_{p1_t} - \bar{p}_{1t}\right) \bar{Q}_{1t} + \left(p_{p2t} - \bar{p}_{2t}\right) \bar{Q}_{2t} \leq B_t$

In this case $\Gamma = \begin{bmatrix} 3460 & 3410 \\ 64 & 121 \end{bmatrix}$

(where the elements of Γ are nutrients content in 1000 gms of each commodity)

Since p_t, p_t^d and y are exogenous, the part (i) of the constraint system reduces to

$$a_{31}\,\bar{p}_{1t} + a_{41}\,\bar{p}^{-d}_{1t} \geq Q_1 - a_{01} - a_{11}\,p_{1t} - a_{21}\,p^d_{1t} - a_{51}y$$

$$a_{32}\,\bar{p}_{2t} + a_{42}\,p^{-d}_{2t} \geq Q_2 - a_{02} - a_{12}\,p_{2t} - a_{22}\,p^d_{2t} - a_{52}\,y$$

For illustration sake, rewriting entire problem with some numerical figures, we have

$$\text{Min. } (J_i) = \sum_{t=1}^{T} - \left(-\begin{bmatrix} 3460 & 3410 \\ 64 & 121 \end{bmatrix} X \begin{pmatrix} 246.5 - 0.3\,\bar{p}_{1t} + 0.9\,\bar{p}^{-d}_{1t} \\ 26.1 - 0.4\,\bar{p}_{2t} + 0.8\,p^{-d}_{2t} \end{pmatrix} + \begin{pmatrix} 766500 \\ 20075 \end{pmatrix} \right)$$

(with reference to $\bar{p}_{it}$'s) $\qquad (i=1,2)$

i. e. $J_1 = -1038\,\bar{p}_{1t} + 3114\,\bar{p}^{-d}_{1t} - 1364\,\bar{p}^{-d}_{2_t} + 2728\,\bar{p}^{-d}_{2_t} + 175391$

$J_2 = 19.2\,\bar{p}_{1t} + 57.6\,\bar{p}^{-d}_{1t} - 48.4\,\bar{p}_{2_t} + 96.8\,\bar{p}^{-d}_{2t} - 1140.9$

subject to

$$(i) \quad -0.3\ \bar{p}_{1t} + 0.9\ \bar{p}^{-d}_{1t} \geq 0.65$$

$$-0.4\ \bar{p}_{2t} + 0.8\ \bar{p}^{d}_{2t} \geq 0.396$$

$$(ii) \quad (p_{p1t} - \bar{p}_{1t})\ \bar{Q}_{1t} + (p_{p2t} - \bar{p}_{2t})\ \bar{Q}_{2t} \leq B_t$$

B_t, the budget per capita can lie approximately in the range of Rs. 25 to 40 per annum. To arrive at the total demand, population served under public distribution system has to be multiplied with the demaud obtained from behavioural relations, after substituting the solution values of $\bar{p}_t$'s.

Stage 2:

$$\text{Min. } j_k = \sum_{t=1}^{T} \left(- \begin{pmatrix} S_1\ (p_{1t}, \overset{s}{p}_{1t}, p_{p1t}, \overset{s}{p}_{p1t}, p_{1t}) \\ S_2\ (p_{2t}, p_{2t}, p_{p2t}, \overset{s}{p}_{p2t}, p_{1t}) \end{pmatrix} + \begin{pmatrix} \bar{D}_1 \\ \bar{D}_2 \end{pmatrix} \right)$$

(with reference to p_{1t}, p_{p_t}'s) k=1,2

subject to

$$b_{31}\ p_{p1t} + b_{41}\ p^s_{p1t} + b_{51}\ p_{1t} \geq S_1 - b_{01} - b_{11}\ p_{1t} + b_{21}\ p^s_{1t}$$

$$b_{32}\ p_{p2t} + b_{42}\ p^s_{p2t} + b_{52}\ p_{1t} \geq S_2 - b_{02} - b_{12}\ p_{2t} + b_{22}\ p^s_{2t}$$

(Here p^t and p^s_t are considered as exogenous to the system).

Substituting purely arbitrary numerical values, the problem can be written as follows :

$$\text{Min } (j_k) = \sum_{t=1}^{T} \left(- \begin{pmatrix} S_1\ (0.3\ p_{p1t} - 0.2\ \overset{s}{p}_{p1t} - 0.1\ p_{1t} + 3852000) \\ S_2\ (0.4\ p_{p2t} - 0.3\ \overset{s}{p}_{p2t} - 0.2\ p_{1t} + 21\,5000) \end{pmatrix} + \begin{pmatrix} 3852135 \\ 2135505 \end{pmatrix} \right)$$

subject to

$$+ \quad 0.3\, p_{p1t} - 0.2\, p^{s}_{p1t} - 0.1\, p_{1t} \geq 135$$

$$+ \quad 0.4\, p_{p2t} - 0.3\, p^{s}_{p2t} - 0.2\, p_{1t} \geq 500$$

The objective functions (j_k) can be rewritten in expanded form

$$J_i = 0.3\, p_{p1t} - 0.2\, p^{s}_{p1t} - 0.1\, p_{1t} - 135$$

$$J_2' = 0.4\, p_{p2t} - 0.3\, p^{s}_{p2t} - 0.2\, p_{1t} - 500$$

Illustrative above are very simplified formulations of the problem of our concern. In practice, we have about 25 to 50 commodities to be considered in terms of important few nutrients (normally more than 3) over a number of periods (usually greater than 4). Also, the control variables could include many other types of interventions. Thus, the dimensionality of a realistic problem could be very significant. If there is a hierarchical ordering of objectives (like minimisation of calorie gap first, protein gap next, etc), some of the known hierarchical optimisation algorithms could be used for solving the problem. Otherwise, suitable algorithms need to be evolved using the existing alternative methods of handling the problem via numerical techniques for solving multi-criterion opttmisation problems.

Some of the limitations of the above model are :

1. In the formulation of the least cost diets, taking the tastes and preferences, one has to consider the frequency of consumption of different commodities by target groups and such a problem is not within the scope of the present study.

2. In the past, very few items in the food basket were supplied under public distribution system. The estimation of behavioural demand relations with issue prices for all the commodities under consideration is a serious lacunae.

3. The models in consumer sub-system are relevant in controlled economies.

4. The assumption behind the production sub-system is that by regulating the input prices, procurement prices, and supply of input quantities, the desired acreage allocation to different crops and inputs allocation to different competing crops can be achieved. The impact of procurement prices in acreage allocation decisions have to be examined. Most of these variables are not within the control of regional authorities. A price structure optimal to a region may not be optimal to other regions and for country as a whole. Price policy designed from nutrition angle per se, may not be consistent with other objectives (of the nation). However, the nutritional dimensions of various price policies can be assessed from the model.

5. There is no explicit recognition of trade aspects in the model. In a production plan, for nutrition viewpoint also, the inter-regional trade aspects have to be incorporated (see policy chapter). The estimation of behavioural production relation has no meaning in cases where a commodity is not produced due to hydro-geological conditions but is consumed by way of imports.

6. The reliability of the model for long-run policy purposes, depends upon the stability of the structural coefficients in the constraint set. The changes in technology for different crops as a result of government interventions, will change the technological relations over time.

7. This model fails to provide special intervention strategies to improve the nutritional status of pre-school children, and pregnant and nursing women.

Computational Aspects

The stage 1 of the model deals with the household decision problem in arriving at the least cost diet. For computational convenience, only issue prices are considered here,

though open market prices can also be included. In the first instant, about seven nutrients and five commodities were considered for the purpose of arriving at the minimum cost of the diet. The solution of this problem, usually consists of two or three commodities with abnormal values, which is not consistent with either food habits or the quantities normally consumed by the consumers. The most commoly consumed items have not been adequately represented in the solution and is usually dominated by some of those which are not regularly consumed. Though it is felt, that enlargement of commodity set will widen the choice and will take care of tastes and preferences, one has to consider the frequency of different commodities consumed by the target population and such a problem is not within the scope of the present study. We have raised the number of commodities to fourteen keeping in view the data requirements and dimensionality of the problem, which would be quite significant when stages 2 to 4 are introduced.

We have attempted to introduce intervals or range in regard to the consumption of commodities, to make the model more comprehensive. Obviously, the ranges prescribe lower and upper limits on the intake of foods under consideration. In most of the cases, the solution touched the boundary values and this poses another problem, namely, the sensitivity of the solution with respect to the intervals. But for Vitamin A, the fourteen food items introduced are quite adequate to give the minimum nutritional requirements stipulated. Since the presence of vitamin A in most of the commodities is negligible, the solution raises the levels of other nutrient intakes quite abnormally while meeting the vitamin A requirement. Hence, it is felt that vitamin A be restricted to 1,000 I. U. instead of around 5,000 I. U., the difference is expected to be met by synthetic vitamin. We have imposed an upper limit on calories which takes care of not only calories but also proteins and to some extent possibly other nutrients also. The fixation of upper limits are justified since the excess intake of

nutrients over and above the tolerable limits are harmful to health. At this stage, the intervals already introduced on food items have been slackened and the upper limits of the interval are left open after careful examination of the results and the implications of the restrictions in operation. With these restrictions on food items (cultural constraints) and nutrients, the system behaved properly and the least cost diet obtained is satisfactory by logical considerations. The Tamil Nadu food habits survey by ORG, Baroda, has been considered in prescribing the lower limits on the consumption of the commodities.

In the second stage, demand relations for each of the fourteen commodities are considered. The functional form of the behavioural demand relations are as follows :

$$D(.....) = f(\bar{P}, \bar{P}_d, p, p_d, y)$$

where

P is open market price of the commodity

P_d is open market price of the substitute commodity

$\bar{P}$ is issue price of the commodity

$\bar{P}_d$ is issue price of substitute commodity, and

Y is the income level.

The objective function of this stage is the minimisation of cost of distribution of the public authorities. Obviously, some of the aforesaid commodities are not issued through the public distribution system, but for operati nal convenience, it has assumed that all the fourteen commodities are to be supplied through the public distribution authorities. The coefficients in the objective function are quantities of these commodities to be issued. In our exercise, the objective function coefficients were taken approximately 1/3 of the demand for the commodities in the initial year. In this model, $p' p_d$ and Y are treated as exogenous. Since the main purpose of

having distribution system is to supply food to the needy or vulnerables at prices lower than the open market level, the solution values have been restricted to be lower than the open market price level. The solution obtained at this stage is fed back to stage 1, and, stage 1 and 2 are repeated. The process is continued till the system is stabilised. It is assumed that the system is stabilised if the two successive feedbacks yield either the same solution in stage 2 or the difference in corresponding values of the variables is not greater than 10 per cent. The prices obtained in the stable solution of stage 2, have been substituted/plugged in the behavioural demand relations and the demand for different commodities have been estimated.

Having studied the intervention policies in the consumer sub-system, we attempt to regu'ate or prescribe appropriate intervention strategies in the production sub-system so as to meet the demand. Since the demand for nutrients have been translated into demand for fooods, we will consider the supply of food items only. It is desirable to consider the interaction at the producer level or farm level decisions and at the macro or aggregate level decisions. In the absence of information regarding stage 3 of the integrated model (which has to be fed from IIMA Study), we have to confine our attention to stage 4, the model which aims at bringing the gap between demand and supply of commodities. Obviously, this pars of the exercise does not involve feed-back process and stability problems.

In this model, the constraint system comprises the behavioural supply relations :

$$S = f(P, P^s, P_I)$$

where P and P^s , are the procurement prices of the main and substitute commodities and P_I is the input prices. By treating P_I as exogeneous, the system reduces to

$$S(.....) = f(p, p^s)$$

once the solution is obtained at this stage, we move to solving the problem for the next period.

The following assumptions have been made in a multi-period analysis. They are: the initial prices for stage 1 for each period is assumed to be known and some guess estimates of prices have been assigned for testing the model. Alternatively, one may assume some relevant growth rate for these prices and increment them over periods. Correspondingly the open market prices used as upper limits in stage 2 also may either be supplied or inflated (For testing we assume that both the prices are known). It is also assumed that the objective function coefficients in stages 2 and 4 of the problem increase at different growth rates. With these above assumptions we tried to work out the problem for 2 periods only. Since in the model, P, P_d and Y in stage 2 and P_1 in stage 4 are treated exogenous, the constant terms in the behavioural relations need to be adjusted, since these variable present in the main relations (before being treated as exogenous) and are incremented over periods. For the sake of testing, instead of having the actual values and their increments over periods, we have simply adjusted the constant term. However, the appropriate procedure would be to arrive at the resultant equation from the main equations where these exogenous variables are incremented and then the equation be reduced to the present form. The results are provided in the following paras. It may be noted since the majority of the input data is arbitrary, the results may not be reliable. However, one may get an insight into the model functioning by comparing the results over periods. With this motive, a few results were obtained and the sensitivity of results vis-a-vis changes in exogenous factors were examined.

The data requirements for the models mentioned in this chapter are:

(a) Consumer Sub–systems

(1) Data on size of population by : (a) age, (b) sex, (c) occupation, (d) income group, (e) social classes, and (f) region; (2) data on food habits in (a) different regions, and (b) different social groups; (3) minimum nutritional requirements for each age group, occupation, and sex; (4) average nutritional intake by different age groups, occupational groups, etc; (5) extent and nature of nutrition gap in various age, sex, occupation, income, and social groups; (6) average food expenditure (budget) for various income, and occupational and social groups; (7) quantity of food items issued for different classes of consumers; (8) composition and total government subsidy in the consumer system, commodity-wise for different classes; (9) time series data on prices of various commodities. retail, issue, and market, including differential prices wherever exist, and income of different occupational and social groups; (10) tables for conversion of food commodities into nutritional equivalents; (11) data on transport costs and purchase price, etc, in case of imports; (12) feeding programmes.

(b) Production Sub—system

(1) Region–wise data on (a) cropping pattern, (b) acreage under different categories or classes of farmers, or rates; (2) time series data on prices of crops and inputs — wholesale market, controlled procurement, etc; (3) quantity of food items procured; quantum of inputs subsidised; and (5) government subsidies in the producer system—taxes, subsidy on agricultural inputs, etc.

Summary Results of Two—Stage Model

1. Least Cost Diet (at 1977–78 prices) :

Commodity	Amount (in K_g)
Rice	0.250
Wheat	0.167

Bajra	0.236
Jowar	0.040
Blackgram	0.010
Redgram	0.025
Bengalgram	0.005
Greengram	0.005
Tomato	0.010
Carrot	0.010
Pepper	0.003
Chillies	0.005
Chicken	0.002
Mutton	0.005

Cost = Rs. 1. 59

2. Quantity of Nutrients

Nutrients	Unit	No of units
Calorie	K Cal	2,478.4
Protein	Grams	67.2
Calcium	mg.	269.9
Iron	mg.	45.1
Vitamin A	I. U.	1,000.0
Thiamin	mg.	2.4
Riboflavin	mg.	1.3

6

Concluding Remarks

In this Study, we have examined, to start with, the physiological aspects of specification of nutritional requirements so that these could give some guidelines for evolving nutr tional intervention programmes and models. The various critical stages of biological growth, the role of various nutrients in different stages, the specification of nutritional requirements, and the limitations of the same along with the inter-relationship between nutrients are also discussed in Chapter 2. We also attempted at formulating a model which may be useful in depicting the nutritional status as well as providing a frame work for achieving an ideal nutritional status. It is observed that the specification of nutrition requirements for different categories of population remains still a complex problem and further work in this area is urgently called for.

Chapter 3 deals with the formulation of consumer demand system models from an economic and behavioural approach. In order to gain an insight into the formulations that have been attempted in literature, a brief survey of literature in this area along with tentative formulations is carried out. The role of agricultural and non-agricultural food commodities in determining the supply of nutrients is also briefly examined and tentative formulations governing the supply of nutrients are attempted. Chapter 4 deals with a detailed survey of various models dealt in the literature in respect of consumer systems as well as production systems from the point of view of nutritional requirements. It is observed that there are limited number of studies which

made effort to integrate the demand and supply aspects integrally. Chapter 5 which is the crux of the study, provides an integrated system for planning nutritional intervention. For this purpose, various alternative models with varying objectives are formulated. According to our understanding, such comprehensive models are not reported in literature. At the end of this chapter, using trial data, the computational experience are reported for one set of these models.

Nutrient Deficiency Diseases

Nutrition Deficiency in Adults

There has been a lot of debate on the reversibility of impact of malnourishment that may accure at an early age. For some "the evidence is becoming more and more weighty that malnutrition in infancy permanently affects the minds of children who have been afflicted".[57] For others, some conclusions on the permanent effects seem correct. Malnutrition and undernourishment are important associated causes of the high death rates among adults, although not so commanding as among infants and young children. The relative impact of malnourishment as a factor in weakening resistance to otherwise non-fatal diseases (or of childhood malnutrition on later adult health status) has not been carefully studied as a cause of adult mortality. Nor has the relative effectiveness of nutrition been investigated as an alternative to vector control and other such methods of attacking local causes of morbidities and reducing mortality risks.

It is universally recognised that malnutrition in adults will result in the reduction in physical productivity and reduce the physical and mental status of the offspring. It also reduces the expectancy of life, and the present life expectancy in low income countries is well below the level in advanced nations. It is believed by the researchers that there exists a high correlation between nutrition intake and cancer. However, the exact relation is yet to be established. The following dis-

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57. Myron Winick. Malnutrition and brain development. *Journal of Pediatrics*, May 1969.

cussion is devoted to implications of nutritional deficiencies in the vulnerable age group—children.

The nutrient deficiency diseases that are commonly seen are : (1) Protein-calorie deficiency; (2) vitamin A deficiency; (3) vitamin D and calcium deficiency (rickets); (4) thiamine deficiency; (5) niacin deficiency; (6) iron/folic acid/B_{12} deficiency; and (7) iodine deficiency.

Protein-Calorie Deficiency

The term protein-calorie or protein-energy malnutrition (PCM or PEM) is used to denote a range of conditions which results from a deficiency of either protein or calories or both in varying proportions. At one end of the spectrum lies the easily recognisable condition of Kwashiorkor, which represents a picture predominantly of protein deficiency with relatively adequate or even abundant calorie intake; at the other end lies nutritional marasmus, in which lack of calories is the dominant feature. In between are gradations of mixed malnutrition in which protein and calorie deficiencies of varying intensities coexist.

Kwashiorkor

The fundamental biochemical lesion is caused by a deficiency of amino acids necessary for protein synthesis, which prevents the normal development of all body organs. The biochemical changes in Kwashiorkor include decrease in serum protein, changes in body composition with accumulation of water (edema) impaired activity of hormones, enzymes and other body proteins; disturbed function of kidney (electrolyte disturbances), liver (faulty livers); and nervous system and associated vitamin and mineral deficiencies. Some of the clinical signs seen in the pre-school age group (1-5 years) who are most vulnerable to the disease are : (1) Stunted growth, (2) Edema around lips and legs, (3) Muscle-wasting, (4) Dyspigmentation of skin and hair, (5) Moon-face child who is apathetic and withdrawn.

Nutritional Marasmus

This arises because of an extremely inadequate diet and is seen most commonly in the first year of life. The marasmic child is said to "live on his own meat", for his body tissues waste away to meet energy needs. There is extreme growth retardation and wasting of muscle and of subcutaneous fat. The protein deficiency does not arise due to deficiency in protein intake per se, but because of an insufficient diet, which causes dietary protein to be utilised for energy purposes, making it scarce for synthesis. Treatment with high protein concentrates will not help as the priority is to provide enough food to meet the energy needs.

On a diet marginally deficient in both proteins and calories, a child who happened to have a high protein requirement would develop Kwashiorkor, while one having a high energy requirement would develop marasmus. Marasmus is more common in India than Kwashiorkor.

Vitamin A Deficiency

Vitamin A deficiency is essentially a problem of children because the requirement of this vitamin is the greatest during the period of rapid growth. It is the commonest cause of blindness among children, particularly between 1 and 4 years and is associated with protein calorie malnutrition. Blindness may also occur in infants whose mothers are deficient in vitamin A since in such cases the foetal stores are not built up. In the milk form, night blindness is a symptom and as the deficiency progresses, the conjunctiva becomes dry and lustreless, resulting in xerosis. This is followed by softening and ulceration of the cornea or keratomalacia. If deficiency is prolonged it leads to blindness which is permanent. An estimated two million children are afflicted with blindness from vitamin A deficiency. Administration of massive doses of vitamin A (200,000 IU) orally once in six months to pre-school children helps prevent deficiency occurring through -out

this critical period as a result of hepatic storage of the vitamin.

Vitamin D and Calcium Deficiency

The deficiency of these two nutrients leads to rickets. Infantile rickets is a disease of calcium and phosphorus metabolism which occurs when infants are weaned on predominantly cereal diets and receive insufficient vitamin D to assist the absorption of calcium from the intestine. In addition, the intake of calcium is usually low because of insufficiency of milk in the diet. Fully developed cases of rickets present the following characteristics: (1) Delayed closure of the fontanelles, softening of the skull; (2) enlargement of wrist, knee (knock-knees), and angle joints ; (3) soft fragile bones,leading to enlargement of the epiphyses of long bones; (4) lack of muscle tone (pot belly) and (5) delayed dentition. The two essentials of the treatment are the provision of a supplement of vitamin D and an ample intake of calcium. Codliver oil or halibutliver oil or a massive dose of vitamin D (600,000 I. U) can be used with oral supplements of calcium (calcium lactate) or an adequate milk-intake. Signs of healed rickets persist with age; and knock-knees, bow-legs and deformities of thorax are seen in malnourished population. Osteomalacia or "adult rickets" causes softening of the bones, rheumatic type pain, general weakness and spontaneous multiple fractures.Since general malnutrtion is always present, osteomalacia is treated with a high protein, high-calorie diet and therepeutic dose of vitamin D.

Thiamine Deficiency

Mild deficiency is characterised by fatigue, emotional instability, irritability, loss of appetite,gastro-intestinal disturbances, etc. When deficiency is prolonged and severe, the disease "beri–beri" results. The clinical manifestations include edema and cardiac failure, and multiple neuritia symptoms. Muscles become wasted and walking becomes

difficult.Treatment is given with all B-complex vitamins, rather than thiamine alone. Associated dietary deficiencies of calories and proteins must also be rectified to cure the disease. Infantile beri-beri occurs in breast-fed infants below six moths whose stores of thiamine as well as intake is poor.

Niacin Deficiency

This leads to pellagra which may also arise due to (i) low tryptophan content of diet (maize eaters), (ii) high leucine content of diet (jowar eaters), and (iii) leucine-isoleucine imbalances in diet. A charactertstic symmetrical dermatites on the exposed surfaces of the body is seen in pellagra. The final stages of the disease are the four Ds–dermatitis, diarrhoea, dementia, and death. Scarlet and raw tongue with fissuring, sore mouth and throat, with fatigue, restlessness, anorexia, are other symptoms. The treatment consists of not only niacin administration but also providing an adequate diet with good quality protein which will correct the amino acid deficiencies and imbalances in the diet.

Deficiencies of thiamine, riboflavin and niacin do not occur alone and the symptoms are seen to overlap. Aribroflavinosis (deficiency of riboflavin) causes cheilosis (cracks at mouth corners), a greasy eruption of the skin, scrotal and vulval dermatites, majenta tongue; angular stomatitis and corneal vascularisation. Glossitis caused by riboflavin deficiency is accompanied with pellagra symptoms and treatment of all the above vitamin deficiencies consists of supplementing the diet with all B–complex vitamins to correct the associated deficiencies.

Iron, Folic Acid, or Vitamin B_{12} Deficiency

Deficiency of any of these or more leads to anaemia. Anaemia is a condition in which there is a reduction in the total circulating hemoglobin. It results in a decreased ability of the blood to carry oxygen to the tissues, which, in turn, is

responsible for varying degrees of skin pallor, loss of skin tone, weakness, headache, loss of appetite, gastro intestinal disturbances, nervousness, palpitations, breathlessness, etc. Deficiency of iron leads to microcytic, hypochromic anaemia, because of the lack of sufficient hemoglobin within the cells. Hypochromic anaemia may occasionally occur coincident with marked protein deficiency. This is seen commonly in infant, adolescent girls and pregnant and lactating women whose needs are greater than normal. Oral iron supplements, or inclusion of good iron sources in the diet with an adequate protein intake will cure the anaemia. A good ascorbic acid intake helps in conversion of ferric form to ferrous form and promotes intestinale iron absorption. Microcytic anaemias ere caused primarily by deficiency of folic acid and its active form folimic acid and/or vitamin B_{12}. The lack of either of these vitamins interferes with the synthesis of nucleic acid and nucleo-proteins so that large, nucleated red cells (megaloblasts) are discharged into the blood circulation. Pernicious anaemia is caused by the lack of intrinsic factor in gastric juice which is necessary for absorption of vitamin B_{12} from the stomach.

Deficiency of vitamin B_{12} causes neurologic changes in the body. While administration of either folic acid and or vitamin B_{12} may cure the megaloblastic state, only vitamin B_{12} is effective in curing the neurologic changes. An associated mineral and vitamin deficiency is commonly seen with anaemia, the dietary treatment should ensure good supply of calories, protein, minerals, vitamins of B–complex group as well as iron, B_{12}, and folic acid to cure the anaemic state.

Iodine Deficiency

This leads to a condition called goitre. Endemic goitre is a term applied to an enlargement of the thyroid gland

which is the result of an inadequate intake of iodine, and is restricted to certain geographic regions where the soil has a low iodine content. It is usually seen in the Himalayas and a few hill areas of Andhra Pradesh. In iodine deficiency, the thyroxine (hormone secreted by thyroid gland) level in the blood is lower than normal, which stimulates the thyroid gland to greater action, tending to cause it to enlarge. Adolescence is the period of greatest susceptibility to limited iodine intake, and the female sex is afflicted with endemic goitre more often than the male. Iodine deficieny during growth may lead to cretinism, where the individual is physically and mentally retarded. Cretinism occurs in an infant when the pregnant women is so severely depleted that the supply for the foetus also is limited. The incidence of cretinism and deaftmutism is high in goitrous areas. Treatment consists in giving iodine supplements. The iodization of salt in goitrous areas has helped in prevention of the disease.

Protein Quality Assessment Indicators

The quality of a protein has been expressed in several ways and a few common methods are discussed below.

Chemical Score (Amino Acid core)

The system of chemical scores as devised by Block and Mitchell[58] is based on the amount of essential amino acids in greatest deficit in a protein compared to the level present in a reference protein. Block and Mitchell suggested that since all amino acids must be present at the site of protein synthesis in adequate amounts for protein synthesis to proceed, as equal percentage deficit of any essential amino acid would limit protein synthesis to a comparable degree. The reference protein (egg, or human milk protein) is considered to be an "ideal protein" which contains all the essential amino acids in sufficient amounts to meet the requirements without any excess. The most limiting amino acid — the one in greatest deficit — would presumably determine the nutritive value. FAO/WHO study[59] has given a new provisional scoring pattern (based on derived estimates of human amino acid requirement) which is considered preferable to the use of the protein of whole egg or human milk. Table B.1 gives the provisional

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58. Block R J, Mitchell M H. Nutrition Abstracting. Review 1946 16. 249.

59. FAO/WHO. Report of Expert Committee. WHO. Tech. Report Ser. No. 522, 63, 1973.

amino-acid scoring pattern. The amino acid score of a protein or mixture of proteins is calculated as follows:

$$\text{Amino acid score} = \frac{\text{Mg of amino acid in one gm. of test protein} \times 100}{\text{Mg amino acid in reference protein}}$$

The lowest score obtained for any of the essential amino acids is the chemical score and this may be taken as a first approximation to the probable efficiency of utilisation of the test protein or mixture by children and may permit a rough correction of protein requirement for the quality of dietary protein. This score may underestimate the quality of of the protein for adults, whose essential amino acid needs per gram of protein are known to be lower.

Table B. 1: Provisional Amino Acid Scoring Pattern

Amino acid	Suggested level	
	mg. per G. of protein	mg. per G. of nitrogen
Isolaucine	40	250
Leucine	70	440
Lysine	55	340
Mithionine + cystine	35	220
Phenylalamine + tyrosine	60	380
Threomine	40	250
Tryptophan	10	60
Valine	50	310
Total	360	2250

Source: FAO WHO. *Energy and Protein Requirements*. Report of a joint FAO/-Expert Committee, WHO Tech. Rep. Ser No. 522, 63, 1973.

Biological Evaluation

Protein quality may be evaluated by a biological test of nitrogen utilisation. Biological value (BV) of a protein is expressed as the percentage of absorbed nitrogen that is retained by the body.

$$BV = \frac{\text{retained nitrogen}}{\text{absorbed nitrogen}} \times 100$$

$$= \frac{\text{Nitrogen intake} - (\text{Faecal nitrogen of food origin} + \text{urinary nitrogen of food origin}) \times 100}{\text{Nitrogen} - (\text{faecal nitrogen of food origin})}$$

Biological value is concerned only with the utilisation of absorbed nitrogen. Nitrogen balance is the sum of gains and losses of all tissue proteins of the body. It yields data regarding the suitability of protein to meet the requirements. Nitrogen balance is determined from the equation B = I — (U+F+Skin nitrogen losses) where I = intake, U and F are urinary and faecal nitrogen and B = balance with (U+F) being corrected for nitrogen of endogenous origin.

Net Protein Utilisation

This measures the percentage of dietary nitrogen retained by body under specified conditions, and is a combined measure of digestibility and of the efficiency of utilisation of the absorbed nitrogen.

$$NPU = \frac{\text{Retained nitrogen} \times 100}{\text{Nitrogen intake}} = B\ V\ X\ D$$

Where B V = biological value, D = digestibility and
NPU = Net protein utilisation.

NPU values used to assess the nutritional quality of proteins ard ordinarily determined under conditions in which the intake of protein limits the growth to an appreciable

extent. As the efficiency of protein utilisation is reduced if the energy intake is too low or if the protein is fed in too large amounts, measurements of NPU should be made under standardised conditions, with proteins fed to adults below maintenance levels, or to growing animals at levels that limit growth to about half the maximum rate, in diet supplying adequate quantities of energy and other nutrients.

Such measurements give maximal values and can be used to compare the quality of proteins.

$$\text{N.D}_p \text{ cal \%} \quad \text{or} \quad \text{ND}_p \text{ E\%}$$

This measures the utilisable protein in the diet expressed as a percentage of energy content. The ND_p value represents the utilisable protein in the mixture and is a function of both quality and quantity. Its value is stated in terms of the calories it represents, expressed as a percentage of the total metabolisable calories in the food. The term can be used to express either the protein requirement of a consumer or the protein value of meals and so make it possible to relate one to the other.

$$\text{N.D}_p \text{ calls \%} = \frac{\text{Protein calories}}{\text{Total calories}} \times \text{N.P.U}$$

Protein Efficiency Ratio (PER)

Growth is a sensitive index of the supply of essential amino acids and may be used to evaluate the overall effect of dietary protein. PER is defined as the gain in weight per gram of protein intake of a growing animal.

$$\text{PER} = \frac{\text{Weight gain}}{\text{Protein consumed}}$$

The rate of growth of an animal under defined consideration is used to measure the value of dietary protein and express it as PER. It is also of value in studies on human infants.

Appendix C

Table C.1 : Per Caput Nutrients Needs and Availability in Tamil Nadu

Nutrients	Percapita need for Tamil Nadu population **	* Percapita net availability	Percentage met
Calorie (K.Cal)	2242	2107	94
Protein (gms)	42	49	116
Iron (mg)	23	39	169
Vitamin A (I.U)	4014	1448	28
Calcium (gms)	0.51	0.589	115
Thiamine (mg)	1.20	1.29	107
Riboflavin (mg)	1.30	0.63	48
Niacin (mg)	15.40	17.70	115
Vitamin C (mg)	45	32	71

Source : * Tamil Nadu Nutrition Project, *Food Balance-Sheet*. (1966-67 to 1978-79).

** Need will be greater if unequal distribution is also taken into consideration. Tentatively one may have to plan for 20 to 25 per cent more than the need according to recommendations

Table C.2 Net Availability of Different Food Items / Nutrients (per caput per day) in Tamil Nadu

Average for 13 Years : 1966-67 to 1978-79

Commodity	Grams Per day	Calorie (K. Cals)	Proteins (gms)	Iron (mg)	Vitamin A (I.U)	Calcium (gm)	Thiamine (mg)	Riboflavin (mg)	Vitamin C (mg)
Cereals	383.77	1296	31.58	18	78	0.114	0.95	0.31	N
Starchy foods	20.45	28	0.61	N	26	0.007	0.03	N	3
Sugar/Jaggery	65.06	254	0.13	3	91	0.030	0.01	0.01	N
Grams & Pulses	24.51	83	5.64	2	29	0.029	0.11	0.05	N
Nuts and Seeds	10.21	44	1.12	N	2	0.039	0.02	0.01	N
Vegetables	43.46	18	1.30	6	76	0.117	0.01	0.02	10
Spices and Condiments	9.25	26	1.11	1	50	0.031	0.05	0.03	3
Fruits	106.92	65	1.10	9	928	0.027	0.07	0.07	15
Meat	4.14	18	0.87	N	2	0.001	N	N	N
Eggs	1.24	2	0.16	N	27	0.001	N	N	N
Fish	20.73	13	2.69	N	N	0.011	N	N	N
Milk	86.68	101	3.47	N	139	0.182	0.04	0.13	1
Oils and Fats	17.68	159	—	—	—	N	N	N	N
Total Food	794.1	2107	49.78	39	1448	0.589	1.29	0.63	32

N : Negligible

Source : Tamil Nadu Nutrition Project

(in 000 hectares)

5-76	1976-77		1977-78		1978-79	
B	A	B	A	B	A	B
2363.6	38511	2283.7	40002	2670.0	40196	2713.0
816.9	15772	841.8	16273	768.0	16125	712.0
449.8	10751	456.1	11035	434.4	11341	432.7
25.0	6000	19.2	5700	20.4	5779	19.6
319.9	2496	290.3	2652	321.0	2619	292.4
420.5	4680	468.5	4740	490.0	4457	456.2
470.9	22983	545.3	23536	588.2	23549	598.0
208.1	6885	239.8	7815	304.4	8087	238.1
128.3	2866	154.5	3220	164.1	3119	171.7
1044.4	14834	1013.7	15505	1106.7	15900	1094.0

Appendix D

Trial Results of Optimizing Models

Table D 1.1 : Summary results of 4-stage model

Period number	Feedback number	Stage 1 * (in Rs.)	Stage 2 ** (in Rs.)	Stage 4 † (Rs. in crores)
1	0	0.82	129.60	
	1	0.79	126.60	181.84
2	0	0.90	62.86	
	1	0.73	131.68	
	2	0.75	131.68	201.78

* Least cost diet, per capita, per day

** Cost of interventions in consumer system

† Annual cost of interventions in supply system

Table D 1.2

Commodity	Stage 1*		Stage 2**		Stage 4†	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Rice	0.250	0.250	1.028	0.953	1446.204	1708.331
Wheat	0.139	0.307	1.065	0.838	587.700	1064.357
Bajra	0.074	0.040	0.706	0.691	410.874	121.791
Jowar	0.040	0.040	0.720	0.699	534.041	418.256
Blackgram	0.010	0.010	2.036	2.643	2957.066	3018.220
Redgram	0.025	0.025	2.152	2.744	2861.751	2920.925
Bengalgram	0.005	0.005	1.527	1.478	552.770	563.583
Greengram	0.005	0.005	1.310	1.234	251.399	257.009
Tomato	0.010	0.010	1.000	0.930	1462.125	1492.176
Carrot	0.010	0.019	0.500	1.200	480.755	492.635
Pepper	0.003	0.003	6.880	6.882	6448.105	6578.609
Chillies	0.005	0.005	2.789	2.684	3197.242	3262.393
Chicken	0.002	0.002	1.91	2.254	1745.745	1781.998
Mutton	0.005	0.005	3.631	4.302	3228.994	3298.056
Cost (Rs.)	0.79	0.75	129.60	131.68	181.84+	201.78+

* Least cost diet, per capita, per day

** Price of commodity in consumer system in Rs. per kg

† Price in supply system per tonne in Rupees

\+ In Crores of Rupees.

Table D 2.1 : Summary Results of 4-Stage Model

Sensitivity 1 : X_{11}, X_{12}, X_{13} and $X_{14} \geq 0$

Period Number	Feedback Number	Stage 1* (in Rs.)	Stage 2** (in Rs.)	Stage 4† (Rs. Cr.)
1	0	0.77	168.59	
	1	0.78	50.71	213.91
2	0	0.85	53.94	
	1	0.68	203.95	
	2	1.06	56.62	
	3	0.92	203.95	
	4	1.06	56.62	
	5	0.92	203.95	229.49

* Least cost diet, per capita, per day

** Cost of interventions in consumer system, per capita per annum

† Annual cost of interventions in supply system

Table D 2·2

Commodity	Stage 1*		Stage 2**		Stage 4†	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Rice	0.250	0.250	—	2.200	1106.537	1926.221
Wheat	0.025	0.318	0.722	1.254	1174.325	1500.000
Bajra	0.390	0.040	—	0.691	899.286	121.787
Jowar	0.040	0.040	0.800	0.699	309.264	418.232
Blackgram	0.010	0.010	2.036	2.643	2956.722	3017.838
Redgram	0.025	0.025	2.152	2.744	2861.397	2920.549
Bengalgram	0.005	0.005	1.527	1.478	552.843	563.593
Greengram	0.005	0.005	1.310	1.234	251.423	256.984
Tomato	0.010	0.010	1.00	0.930	1462.208	1492.191
Carrot	0.010	0.022	0.501	1.200	480.752	492.621
Pepper	0.0	0.0	7.470	4.781	4661.727	—
Chillies	0.028	0.0	2.098	1.814	3546.619	—
Chicken	0.0	0.0	—	—	1897.734	1803.403
Mutton	0.0	0.0	—	—	5499.574	5014.984
Cost (Rs.)	0.78	0.92	50.71	203.95	213.91††	229.49††

* Least cost diet, per capita, per day in kgs

** Price of commodity in consumer systems in rupees per kg

† Price in supply system per tonne in rupees

†† In crores of rupees

Table D 3.1 : Summary Results of 4 – Stage Model

Sensitivity 2, $X_3 = 0$

Period Number	Feedback Number	Stage 1* (in Rs.)	Stage 2** (in Rs.)	Stage 4† (in Rs.Cr.)
1	0	0.83	176.80	
	1	1.11	176.80	230.40
2	0	0.91	198.06	
	1	1.20	198.06	261.24

* Least cost diet, per capita, per day

** Cost of interventions in consumer system

† Annual cost of interventions in supply systems

Table D 3.2

Commodity	Stage 1*		Stage 2**		Stage 4 †	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Rice	0.250	0.250	2.000	2.200	1528.196	1926.202
Wheat	0.336	0.336	1.200	1.254	1110.161	1500.000
Bajra	0	0	0.167	1.167	786.901	546.824
Jowar	0.040	0.040	0	0	342.483	212.980
Blackgram	0.010	0.010	2.036	2.643	2957.481	3018.317
Redgram	0.025	0.025	2.152	2.744	2862.117	2021.013
Bengalgram	0.005	0.005	1.527	1.478	552.678	563.552
Greengram	0.005	0.005	1.310	1.234	251.345	256.981
Tomato	0.010	0.010	1.375	0.930	1474.810	1492.187
Carrot	0.021	0.021	1.000	1.200	518.694	492.624
Pepper	0.003	0.003	6.880	6.882	6448.180	6578.645
Chillies	0.005	0.005	2.789	2.684	3197.290	3262.417
Chicken	0.002	0.002	1.919	2.254	1745.799	1782.058
Mutton	0.005	0.005	3.631	4.303	3229.191	3298.240
Cost (Rs.)	1.11	1.20	176.80	198.06	230.40	261.25

* Least cost diet, per capita, per day

** Price of commodity in consumer system in rupees per kg

† Price in supply system per tonne in crores of rupees

Table D. 4.1 : Summary Results of 4-Stage Model

Sensitivity 3. Stage 1

(Prices of commodities 13 and 14 were raised by 40% in stage 1)

Period Number	Feedback Number	Stage 1* (in Rs.)	Stage 2** (in Rs.)	Stage 4† (in Rs. Cr)
1	0	0.83	129.60	
	1	0.79	129.60	181.84
2	0	0.91	62.86	
	1	0.73	131.68	
	2	0.75	131.68	201.78

* Least cost diet, per capita, per day

** Cost of interventions in consumer system

† Annual cost of interventions in supply system

Table D 4.2

Commodity	Stage 1 *		Stage 2 **		Stage 4†	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Rice	0.250	0.250	1.028	0.953	1446.204	1708.331
Wheat	0.139	0.307	1.065	0.838	587.700	1064.357
Bajra	0.274	0.040	0.706	0.691	410.874	121.791
Jowar	0.040	0.040	0.720	0.699	534.041	418.256
Blackgram	0.010	0.010	2.036	2.643	2957.066	3018.220
Redgram	0.025	0.025	2.152	2.744	2861.751	2920.925
Bengalgram	0.005	0.005	1.527	1.478	552.770	563.583
Greengram	0.005	0.005	1.234	1.234	251.399	257.009
Tomato	0.010	0.010	1.000	0.930	1462.125	1492.176
Carrot	0.010	0.019	0.500	1.200	480.755	492.635
Pepper	0.003	0.003	6.880	6.882	6448.105	6578.609
Chilles	0.005	0.005	2.789	2.684	3197.242	3262.393
Chicken	0.002	0.002	1.919	2.254	1745.745	1781.998
Mutton	0.005	0.005	3.631	4.302	3228.994	3298.056
Cost (Rs.)	0.79	0.75	129.60	131.68	181.84+	201.78+

* Least cost diet, per capita, per day

** Price of commodity in consumer system in rupees per kg

† Price in supply system per tonne in rupees

\+ Crores of rupees

Table D 5.1 : Summary Results of 4 - Stage Model

Sensitivity : Raise in demand vector by 15%

Period Number	Feedback number	Stage 1 * (in Rs.)	Stage 2 ** (in Rs.)	Stage 4† (in Rs. Cr.)
1	0	0.82	129.60	
	1	0.79	129.60	275.79
2	0	0.90	62.86	
	1	0.73	131.68	
	2	0.75	131.68	327.72

* Least cost diet, per capita, per day

** Cost of interventions in consumer system

† Annual cost of interventions in supply system

Table D 5.2

Commodity	Stage 1*		Stage **		Stage †	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Rice	0.250	0.250	1.028	0.838	2000.000	2200.000
Wheat	0.139	0.307	1.065	0.953	1200.000	1500.000
Bajra	0.274	0.040	0.706	0.691	900.000	1099.999
Jowar	0.040	0.040	0.720	0.699	800.000	900.000
Blackgram	0.010	0.010	2.036	2.643	3200.000	3400.000
Redgram	0.025	0.025	2.152	2.744	1949.466	2124.379
Bengalgram	0.005	0.005	1.527	1.478	1160.771	1183.736
Greengram	0.005	0.005	1.310	1.234	677.002	691.120
Tomato	0.010	0.010	1.000	0.930	2405.366	2513.528
Carrot	0.010	0.019	0.500	1.200	1000.000	1199.999
Pepper	0.003	0.003	6.880	6.882	6752.379	7083.453
Chillies	0.005	0.005	2.789	2.684	3549.998	3699.999
Chicken	0.002	0.002	1.919	2.254	2485.074	2536.114
Mutton	0.005	0.005	3.631	4.302	4984.891	5089.078
Cost (Rs.)	0.79	0.75	129.60	131.68	275.79+	327.72+

* Least cost diet, per capita, per day

** Price of commodity in consumer system in rupees per kg

† Price in supply system per tonne in rupees

\+ In rupees crores

Table D.6 : Least Cost Diet for Tamil Nadu

50 Commodities considered

Vegetarian diet :

1. Major cereals (other than maize) to be at least 400 gms and rice to be at least 200 gms. Maize to be less than (or equal) 60 gms. Grams and pulses together to be at least 25 gms. Oil and milk to be at least 15 and 100 gms, respectively. Upper limit in calories is 2,300 K. Cal.

	K. gms
Rice	200
Bajra	412
H. Gram	25
Chillies	50
Drumstick leaves	23
Gronndnut oil	15
Milk	100

Cost of the diet : Ps. 0.95.

2. The constraints at item 1 above being same, chillies resricted to be maximum 15 gms.

Rice	200
Wheat	220
Bajra	166
Horse gram	25
Chillies	15
Drumstick leaves	28
Groundnut oil	15
Milk	100

Cost of the diet Ps. 0.97

Non-Vegetarian diet :

3. The constraint on milk at item 1 above is relaxed. Nevertheless constraints on fish and egg (75 grams and 30 grams minimum, respectively) are imposed.

Rice	200
Bajra	420
Horse gram	25
Chillies	40
Drumstick leaves	17
Groundnut Oil	15
Fish	75
Egg	30

Cost of the diet : Rs. 1.10

4. On diet at item 3 additional constraint on chillies is introduced (chillies to be maximum 15 grams).

Rice	200
Wheat	131
Bajra	274
Horse gram	25
Radish	13
Chillies	15
Drumstick leaves	20
Groundnut Oil	15
Fish	75
Egg	30

Cost of the diet : Rs. 1.11

Vegetarian Diet :

5. The constraints are same as in item 2. The only change is with respect to the upper limit on total cereals (other than maize) which now is 450 gms.

Rice	200
Wheat	250
Maize	60
Horsegram	82
Radish	75
Chillies	15
Drumstick leaves	28
Groundnnt oil	15
Milk	100

Cost of the diet Re. 1.00

6. The constraints are same as in item 5 above. The only change is that wheat is forbidden for consumption.

Rice	200
Bajra	250
Maize	60
Horsegram	106
Radish	202
Chillies	15
Drumstick leaves	23
Groundnut Oil	15
Milk	100

Cost of the diet Rs. 1.02

7. Upper limit on cereals including maize is 450 gms. Other constraints are same as in item 6 above.

Rice	200
Bajra	250
Horsegram	173
Radish	140
Chillies	15
Drumstick leaves	23
Oil	15
Milk	100

Cost of the diet Rs. 1.02

8. Maximum limit on cereals including maize is 450 gms ; maximum maize is 60 gms and rice at least 200 gms, wheat being forbidden. Oil to be at least 15 gms, grams and pulses put together at least 25 gms, chillies maximum 15 gms, fish and egg at least 75 gms and 30 gms, respectively. The upper limit on calories is 2,300 k. cal.

Rice	200
Bajra	250
Horsegram	182
Radish	110
Chillies	15
Drumstick leaves	17
Oil	15
Fish	75
Egg	30

Cost of the diet Rs. 1.17

50 Commodity Set

Cereals
1 Rice
2 Wheat
3 Ragi
4 Bajra
5 Jowar
6 Maize

Grams and pulses
1 Red gram
2 Bengal gram
3 Green gram
4 Black gram
5 Horse gram

Starchy Food
1 Potatoes
2 Sweet potatoes
3 Beet root
4 Onion

Vegetables
1 Brinjal
2 Bendai
3 Tomato
4 Radish
5 Chillies
6 Cow pea
7 Snake gourd
8 Plantain

Leafy Vegetables
1 Amaranth
2 Araikeerai
3 Cabbage
4 Drumstick leaves
5 Drumstick
6 Field Beans
7 Carrot

Fruits
1 Banana

Nuts
1 Coconut
2 Groundnut

Oils
1 Groundnut oil

Sweet
1 Sugar
2 Jaggery

Spices and condiments
1 Chillies (dry)
2 Tamarind
3 Turmeric
4 Pepper (dry)
5 Garlic
6 Cumin seeds
7 Mustard seeds

Meat
1 Sheep
2 Pig
3 Chicken
4 Duck
5 Fish

Egg
1 Hen

Milk
1 Buffalo